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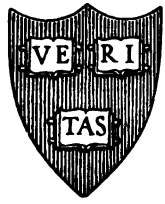

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ERRATA.

Page	4,	line 29,	for	"combination," read "combinations."
——	5,	— 16,	—	"seat," read "heat."
——	19,	— 20,	—	"holopticheus," read "holoptychius."
——	43,	— 27,	—	"axis," read "axes."
——	50,	— 29,	—	"Burdic," read "Burdie."
——	55,	— 23,	—	"*minimas*," read "*minimus*."
——	57,	— 14,	—	"sinkings," read "borings."
——	61,	— 10,	—	"red stone," read "red sandstone."
——	71,	— 1,	—	"Ethertow," read "Etherow."
——	82,	— 27,	—	"Icthyology," read "Ichthyology."
——	88,	— 7,	—	"Parron," read "Parson."
——	188,	— 25,	—	"plate II," read "plate VIII."
——	190,	— 26,	—	"plate II *a*," read "plate IX."

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THE

TRANSACTIONS

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ART. I.

On some of the Objects and Uses of Geological Researches. By J. Black, M.D., F.G.S., &c.

From the earliest records of mankind, we find that the nature and motions of the heavenly bodies have attracted the attention and study of the curious and contemplative; and so continued and intense has been the inquiry of the human mind, from the remotest ages, to gain a knowledge of the forces and laws which govern them, that successive systems have been invented, having their origin in superstition and speculation, till, at length, one of mathematical proof has been deduced, on which the civilized and intelligent mind of man now rests in undiminished wonder, but in rational and satisfactory repose.

The sublimity of the science of astronomy, and the vastness and loftiness of its objects and laws, have carried it so far above any relation to what occurs in such a comparatively small speck of the universe, as our globe is, that it is only in the calculations of our almanacs, or when we

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traverse the surface of the ocean, or the extended desert, that we ever make the grand theorems of this sublime science subservient to our temporal and perishable purposes. The objects of astronomical study are transcendental, and unbounded as infinity; while their useful and economical bearings are few, simple, and precious: they are, as being of a celestial nature, far more adapted to instruct, improve, and elevate the immortal part of our nature, than to administer to the desires and wants of our bodily frames.

Leaving the lofty regions of this first of sciences, we lay hold on that of Geography, which, though deriving its birth from its celestial parent, and founded on heaven-born laws, yet offers its more condescending and familiar hand, to lead us in those paths of knowledge, that have a more diffused and intimate connection with the conditions and fortunes of our race.

In the higher departments of this science, we are informed of the configuration of the earth, the great lines of the distribution of land and water, and of the elevations and depressions of the surface, with their corresponding climates and productions; and, in its more extended application to man, as a social being, it lays out the boundaries of nations, races, and families, their external political relations, and, finally, the sites of their cities and habitations. In all this extensive sphere of scientific and useful knowledge, which should be the object of every member of social, commercial, or political life to acquire, it is to be remarked, that we have chiefly to do with the superficies of the earth—including its areas and distances. The objects of geographical study are all facts, open and visible, and are not dependent on experiment, induction, or reasoning, except a few which, by mathematical demonstration, are connected with astronomy.

A person may, moreover, be well versed in geographical science, may have traversed the earth from pole to pole,

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and have become acquainted with every divisional line and contour of its physical surface, and with every thing that moves and lives upon it, yet be ignorant of the world that lies beyond our atmosphere, and also of that great field of nature's works which are deposited beneath his feet. The one region may be as much above as the other is beyond his ken; and, as he may suppose the study of the nature and motions of the heavenly bodies to be far above its being applied to any purposes of human and practical utility, so he may conceive, that, beyond the bright metal or coal of a mine, the earth contains, like the pages of ancient history, little but what leads to fable, superstition, or infidelity.

At this stage in the order of human knowledge and inquiry, we have to pass into a new field of nature, which is no less fertile in its objects, and as wide, and often more recondite in the range of its study, than any of the two sciences which have already been mentioned. Where the finger of Geography points only to the surface of the earth, and to what grows and lives upon it; the Science, to which we intend to draw a little attention, takes up the torch of knowledge, penetrates the outer mantle of the globe, and carries research and inquiry into its inmost recesses. And what is worthy of remark, that however far removed the labours and study of the Geologist may apparently be from the loftier objects of astronomical inquiry; and however much his progress is facilitated by a necessary acquaintance with the phenomena and laws belonging to the visible and living world, yet in the deeper investigations that occasionally force themselves upon his mind, he has occasion to revert to the sublimest of all sciences, to account for many of the phenomena which he often witnesses in the crust of the earth.

In the depth of a mine, or the elevation of a mountain, he sees many things which neither geography, botany, nor

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zoology can unravel, but which have a connection with the system of the universe, and with what is called physical astronomy. Thus is completed in the foundations of the earth, this great circle of science, which, divided by the limited minds of men into separate departments, is but one universal system of order and formation, instituted by the Great Architect of nature, who made all things according to the pleasure of his will, and pronounced them good.

In making the few following observations on some of the Objects and Uses of Geological Researches, we shall briefly notice, in the first place, those objects which principally invite our attention, from their interest and importance as matters of intellectual study, and again those which have a practical value or relation to the useful and economical purposes of life.

The science of Geology, in its extended study, investigates those traces that are indelibly impressed on the outer crust of our planet by the successive revolutions which it has undergone, and attempts to elucidate the history of those stupendous physical actions, the effects of which we in so many places so conspicuously witness. It also associates itself with those branches of knowledge, which relate to mineralogy, zoology, and botany—drawing from each of these wide spheres of study, the important supplementary information regarding numerous species of beings which once lived on the earth, but which have long since vanished from the actual condition of things. Geology thus unexpectedly and progressively extends our views of the various combination of organic forms; and, in many instances, it supplies links in the chain of nature, which were otherwise wanting, to complete the several terms of the series of organization.

If we descend from these higher views of scientific interest, to the more practical consideration of the application of geology to the useful and economical arts, on which

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social comfort, national wealth and power depend, we cannot undervalue a science which guides us to the more full development of our mineral resources; which indicates the proper line and localities in which researches for minerals, as coal, may be most successful; which points out to the planter and agriculturist, from the strata beneath, the vegetable productions for which the incumbent soil is best adapted, and how it may be improved, or altered if unproductive; and which instructs us in the best lines for carrying roads and canals through a country, and of selecting the most profitable and durable materials for public and private buildings.

To the lover of science, simply for its own sake, there is "ample room and verge enough" for the exercise of the profoundest intellect, in the great problems of the central seat of the earth, and the consideration of its dynamical effects at different geological eras—of the nature of the original envelope of the earth—and of the successive deposits upon its surface, but which are now found in such an entombed, elevated, mingled, and disturbed condition, that it is a question of very refined inquiry and reasoning to ascertain which is the more primeval of all the various rocks and strata, which are now accessible to our examination. The decreasing temperature of the globe, and its intermittent periods of local and severer refrigeration, with all their relations to climatorial effects on animal and vegetable life —aided and increased in interest by the disclosure of accumulated groups of organic remains from many parts of the world and from various stratified depths, also present a field for observation and study—which, while it cannot but excite wonder and ennoble the mind, calls for the highest powers of reasoning and induction, which have their analogies only in the more exalted departments of human knowledge.

It is not easy to understand how the study of these sublimer subjects of the science of geology, could ever have

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been viewed as having the least tendency to disparage or affect the faith in revealed truth. The book of visible nature can never, in any well constituted and honest mind, be supposed to be in opposition to the page of revelation. It must rather be held as axiomatic, that they must be in perfect harmony, as they both emanate from One and the same Great Author, however much the organs of finite and imperfect creatures, as we are, cannot, at all times, nor in many instances, perceive the exact concordance and relation; for we may truly with the poet say—

> "All discord, harmony not understood;
> All partial evil, universal good."

Even if the study of geology were as perfect and harmonizing, as the most sensitive critic of the science could desire, we might indeed have many more evidences of the power and design of the Creator brought down to our weak conceptions; but, after all, we could never in the most exalted or refined sphere of its studies, nor yet in any other natural science, find out a Redeemer, to declare whom appears to be the beginning and end of revelation.

In addition to these remarks on the study of Geology, we, moreover, have great confidence in averring, that in the whole circle of the natural sciences, we know none which gives so much support, if it were in the least wanted, to the statements of Revelation, as to the creation of the world and the power and interference of the Deity. We find, for instance, in examining the strata of the earth, that there was a time, before which the foundations of the hills were laid; and that the world of animal life had a beginning, from there being no evidence of organized remains found in the rocks beneath the transition strata, and in these, only the first and simple forms of animal and vegetable existence, such as the marine *algæ*, *zoophytes*, and some *radiaria;* while as we ascend through the upper

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and more recent strata, we successively meet with the remains of a more developed and varied existence, both in animals and vegetables, till we arrive at the present order of beings on the surface of the earth.

After what has been written on this subject by others, it is almost trite to remark, that we have the remains of these orders of creation entombed in the crust of the earth, with more or less intermixture, but yet in distinct superposition —all arguing such a chronological succession as is detailed in the Book of Genesis, with the absence, however, of any fossil remains of the last work of creation, namely man. This exception is easily explained, from the surface of the earth, when man became first its inhabitant, not being greatly different from what it now is; and consequently his remains would soon become dissolved in the superficial covering of the deepest sepulchre, when compared with the conservative and still deeper tombs in which nature had successively deposited the remains of pre-existent life.

The same amount of corroborative evidence from fossil geology, as well as from the evident succession and consolidation of rocks, thus afforded to the independent records of Scripture, is wanting in any other natural science, even in Astronomy itself—the sublime objects and machinery of which appear of themselves to have been without a beginning, as they betray no tendency ever to change or perish.

In all the successive orders of creation, we have many beautiful confirmations, that the being, whether animal or vegetable, was formed perfect in its parts and functions, for the sphere of its existence—and not, as has been maintained by some fanciful naturalists, in an imperfectedly developed state, to be succeeded by others of the same type in a more perfect growth and structure—resulting entirely from the innate and self-acting laws of organization, primarily imposed. For we find, for instance, the eye of the *trilobite*,

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as perfect an optical instrument as that of the facetted eye of any recent crustaceous insect; the siphunculated and chambered shell of the fossil *nautilus* and *ammonite* seems to be as elaborate and beautiful, as the shell of any of our modern *nautili* or multilocular *mollusks;* and the pinnules and fructification of the fossil *filices* display as much beauty and reproductive structure as any of the ferns of the present day.

The *pterodactyle* is as instance where reptile animals, in the pristine ages of the world, were endowed with capabilities, and of course with more perfect organs, for aerial locomotion, than are now known to exist; and we need not speak of osseous and muscular development, when we compare that of the gigantic *mastodon*, *megatherium*, and the *iguanodon* with what we now see in any terrestrial animals of the modern world.

The successive disappearance of many genera and species of both animal and vegetable remains, with the fresh appearance of others of a different genus and speciality, as we ascend from the ancient strata to those of more recent superposition, affords very instructive evidences of the successive acts of a Creative Power—ever ready to call into existence new tribes of beings, fitted for the peculiar conditions, which the surface of the earth was from time to time undergoing, from physical changes in land and water and climatorial temperature.

But to leave these higher pursuits of the science, which are as ennobling as they are salutary to the mind, we shall next notice a few of those objects, which are more nearly connected with the studies of the natural sciences, in regard to the curiosity, interest, and utility, which they naturally excite and promote. It is impossible in a paper of this description to advert to a tithe of the vast assemblage of objects which lie open for the observation and investigation of the geologist; and it, moreover, requires, at the

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present state of the science, no ordinary attainments, in either zoology, botany, or mineralogy, to be able to observe and investigate, with intelligence and profit, any one of the paths which is limited to either of these three leading branches of knowledge: how much more must be the attainments of him, who is able to bring the whole to bear upon the general field of geology, aided, as they must be, by a competent acquaintance with chemistry and natural philosophy.

Such a rare amount of general knowledge is not, however, absolutely necessary for either the pleasurable or profitable pursuit of geological science. It will be sufficient to be acquainted with any one of the above-mentioned subordinate sciences, to be enabled to observe with interest, and record with utility, an inexhaustible amount of objects, having a strict relation only to the one exclusive study. Even to him, who has never prepared himself by any previous course of study in the natural sciences, to appreciate philosophically the objects of geology; yet if he possess common talents for observation and a contemplative mind, there are multitudes of phenomena that will afford interest, and subjects of reflections, by which the cause of geological science may receive benefit at his hands.

The conformation of rocks by the sea shore, on the mountain, or in the quarry—the inland beds of gravel, the natural terraces upon our hills, submerged forests, and beds of shells at a distance from the sea coast or a river—with the appearance of granite and schistus in one district, sandstone and limestone in another, and chalk and clay in a third—will all naturally attract the attention of such a one, and lead him to consider when and how such different arrangements took place. He will soon begin to find that others have previously wondered at such things, have together compared their observations from different quarters and countries, and found a similarity of appearance

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and of sequences, in meeting with such rocks. He next discovers that similar facts have been recorded; he consults some book on the subject, and his mind advances a few more stages in the study, as he obtains the key to unlock some of his doubts. He observes again—his attention is re-excited, his mind gets engaged—and so he becomes a geologist, without any previous education professedly scientific.

But to the Chemist and Mineralogist, Geology at once lays open a store of objects which readily excites his interest and commands his appreciation, wherever he travels over the surface of the earth. In the early study of the science, acquaintance with chemistry and mineralogy was held to be the sole introductory qualification for the pursuit of geological researches, for the science first sprung up in the schools of Chemistry and Mines, under the auspices of Werner and Hutton; but as it advanced, it has attracted the Botanist and Natural historian, and has received from them some of its most interesting and important elucidations. Notwithstanding this participation, the chemist and mineralogist will retain a large portion of the field of geology for his undivided possession; and as the objects of his study are most widely scattered, they are more generally available for his attention and investigation—besides leading to more practical and economical utility, than those pertaining to either zoological or phytological geology.

Wherever he goes, or explores the crust of the earth, he will find some portion of inorganic matter, which will exercise his inquiry. If it is a fragment on the road side, he will examine its form and composition, and endeavour to trace its origin to some neighbouring rock, or to some stratum, more or less distant. From the pebbles and boulders that are scattered over many a plain and sea-beach, he will be desirous to know, as he may be able to ascertain, whether they were derived from granitic beds,

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limestone ridges, or chalk hills, however distant any of these may be; and hence he will be enabled to trace the direction and force of the aqueous drift that once transported them from their original beds. He may also find some of large size and angular, which have their parent rock at a great distance, but, from their shape and surface, he may suppose they could not have been subjected to any attrition of consequence during their transit; he will therefore naturally look to the agency of floating icebergs or detached glaciers, to solve the problem of their transportation.

If, in traversing the bed of a stream, he finds pieces of dolomite or calcareous spar, especially if containing any pyrites or sulphurets of the metals, he will naturally explore the upper course of the stream, and inquire if there are any mountain limestone, grauwacke or micaceous rocks, in which a search may be, very probably and successfully, made for veins of lead, copper, or some more precious metal. If he further finds that the strata have been disturbed and fractured, near any junctions between granite and the schistose rocks, he will localize his research with a better probability of falling in with the metallic veins.

His knowledge also of the composition of a rock will, in many cases, enable him to identify the strata as belonging to a certain geological era, and how far it may also be available for the arts, and the economic purposes of life. The detection also of greenstone, porphyry, or basalt, will excite his inquiry as to the source and extent of the igneous rock; whether its focus is crateriform, or linear as a dike; and what dislocation or changes it has produced on the proximate and divided strata.

The nature of the surfaces of the strata, through which the igneous rock has been protruded, will also lead him to judge of their comparative chronology; as in horizontal injections of the intruded rock, if the surface of the rock

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next beneath is physically altered, and the under surface of the rock above be not, it will shew that the igneous rock is of posterior date to the one under, and anterior to the other above it; but if both surfaces are altered, then the injected rock, even if granite, will be deemed posterior to them both.

The examination of the outcrops of many strata, will, from their chemical nature, porosity, or adhesiveness, point out how water can be best procured, or disposed of; and the nature of percolating water will not be overlooked, as it may indicate some valuable deposits in the subjacent rocks. I need not mention, how his acquaintance with special mineralogy will enable him to detect the true gem from the impure crystal, among the disintegrated or compact portions of any rock.

Objects of interest and utility are thus continually presenting themselves to the chemical geologist, in otherwise the most barren countries, denuded, as they may be, of anything that is interesting either to the zoologist or botanist; and even in the application of chemical analysis, and the laws of affinity to the chronology of geology, he has abundant and wide-spread materials for his attention. Thus, though he will find that the constituent elements of basalt, greenstone, trachyte, and porphyry are nearly the same—being composed of hornblende and feldspar; yet from the different temperatures and amounts of incumbent pressure beneath water or sedimentary strata, and the several rates of cooling of the melted rock, he will derive interesting data to account for the modified forms of the same chemical constituents.

The application of chemistry, directed to the comparative analysis of coal as fitted to various purposes of the arts, and the examination of sedimentary or other deposits in rivers, lakes, and sea-estuaries, for to ascertain whence they are derived—whether from the coast or from

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disintegration of the interior by water courses, are subjects frequently calling for attention and solution. Even great interest will at times be afforded to the chemist, and assistance rendered to paleontology, by his examination of fossil teeth, scales, and bones—which, from being found to contain either phosphate, fluate, or carbonate of lime, indestructible enamel, or mere dental impressions, will throw considerable light on the identification of the remains, whether belonging to a fish, saurian, or a mammifer.

To the Botanist, the Flora of Geology offers no less fertile a field of objects to excite the highest interest, and to provoke the most pleasurable research; though it cannot be said the investigation leads to such economical or useful results, as the researches of the chemical geologist do. As the objects of botanical science relate much to colour, growth, and symmetry of form, so they are more interesting and pregnant with delight to our senses, than any conformation of inorganic matter, with the exception, perhaps, of the precious gems; and correspondently, the fossil remains of the primeval flora, especially as they exhibit such exotic and extraordinary forms and organization, are, with the exception of colour, full of interest, if not of wonder, to the student of this branch of natural science.

Whether he traces the earliest marks of vegetation from the marine *algæ*, or sea weed of the grauwacke, to the remains of the cocoa palm, the pine, the poplar, and the elm in the tertiary strata, he cannot fail to be supplied with successive orders of vegetable remains, that must necessarily engage his inquiry, as to the circumstances of soil and climate under which the living plants were produced, as well as to the causes which effected their destruction and entombment in the strata of the earth. The dawn of the terrestrial fossil flora in the grauwacke group of rocks,

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consisting of a few *calamites*, *sigillaria*, *lepidodendra*, and *stigmaria*, he will watch with increasing interest, through the millstone grit and shales, till the vast records of an extensive vegetation are presented to him in the coal measures. In this prolific field of vegetable remains, besides the natural inquiry how far the different plants therein preserved can be identified with recent types or species, as mere objects of botany, the mode in which their remains are so perfectly and beautifully preserved, equal to what they could be in any herbarium—the nature of the enveloping matrix, whether sandstone, shale, or coal—and the probable manner in which they became so accumulated in certain areas, will all awaken a multitude of inquiries and reasonings, that cannot but be of themselves instructive, elevating, and useful to the mind.

The very aspect of the remains of a palm tree, a coniferous stem, or of other fossil trunks that have been discovered, in many places embedded from forty to one hundred feet beneath the solid rock, and from thirty to fifty feet or more in length, and lying in all directions, naturally leads to wonder and inquiry, especially if they are found erect, as if they had grown on the spot. The botanist is first desirous to ascertain to what living species or genus of plants they are allied; and if he find them to have only their congeners in tropical climates, or in very small types in the temperate zones, he concludes the atmospheric influences under which they grew must have been much different from what they now are in the locality examined; and he is further confirmed in his views by finding in the neighbouring strata, remains of gigantic ferns, palm-nuts, and of plants of which he knows no type, neither in warm nor temperate countries. The internal organization of the undefined plant next engages his attention—to see whether he can identify it with a pine tree, or with a hollow or cellular trunk, with or without a pith;

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and lastly, his inquiry is not satisfied till he can attain some satisfactory explanation of the manner in which the plant was fossillized; how its bark became bituminized; its calibre crushed or preserved; and its interior replaced and filled by the material of the surrounding rock, or shale; or whether it was filled from some more remote or more elevated source. With the aid of the microscope, he will be desirous to ascertain the nature of the internal organization of the fossil plant, if any such can be discovered, for in some stems none can be detected. If he finds, however, that there are marks in the hard stone of a textural or cellular configuration—indicating a woody fibre, but without distinct concentric rings, he will be induced to place the living type as having grown in a tropical climate of not much variation of temperature throughout the year, as some of the fossil palms, and coniferæ, which are allied to the Norfolk pine. If the concentric rings are detected, he infers a change of annual temperature like our winter and summer, and that the plant lived in a climate more nearly approaching to our own. In the brown coal of Bonn, a vertical stem, three yards in diameter, was found which had seven hundred and ninety-two concentric rings, which registered the lapse of nearly eight centuries. It need not be said, that however much has been investigated on these subjects, there still remains much to be inquired into and established.

The next object, and one which has long and still engages controversial attention, is, how the vast assemblage of these and similarly situated plants, amounting to above five hundred known species, contributed to the formation of those mighty magazines of coal—so important to man in all his relations, and which are found distributed, in greater or less areas, over many opposite parts of the globe.

In this inquiry several subjects will require the most

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inductive consideration, to arrive at any satisfactory conclusion; first, whether beds of coal were formed from vegetables, plants, and trees that were drifted from the face of elevated lands into the primeval estuaries of seas or fresh water lakes, and there deposited stratum upon stratum, such as is, in a similar manner, witnessed at this day at the mouths of the Mississippi and Amazon rivers;—or whether they were formed from plants that grew and successively died on the spot;—or whether beds of coal owe their principal source to extensive and recurring peat bogs, produced by the different tribes and growths of mosses which flourished on the decayed remains of their predecessors—subjected to be occasionally drifted over by the gigantic *ferns*, *palms*, *lepidodendra*, and *lycopodiaceæ* that grew on their borders and the adjacent lands. Then the order of superposition of the beds, alternated with rock and shale, will become the next object of study. Whether this depended on intermittent subsidence of the whole strata, or on periodical submersion from intruding waters; and, last in the order of his speculative inquiries, the important subject of the bituminization of the vegetable remains, however produced or derived, will engage attention. In this last part of the inquiry, the aid of chemistry must be called in to show, how the submerged plants gradually lost their proportional constituents of hydrogen and oxygen—from the first chemical change in the fossil lignite, till the carbon was the chief element that was left in the anthracite beds.

The botanical geologist will not rest satisfied with these, perhaps, purely scientific objects, but, from his acquaintance with the carboniferous flora, he will be enabled, in a strange or unexamined country, to say whether there is any fair or certain prospect of meeting with the valuable mineral of coal, from the simple inspection of such a remain as a *calamites*, *stigmaria*, or *lepidodendron*, that may

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casually be found in the bed of a river, or on the surface of the country. The evidence of such a specimen will lead him to seek for the great conservatory of plants somewhere in the neighbourhood, however it may be covered over by the forest, the wild savannah, or the morass; while the detection only of a fossil palm, or of some dicotyledonous plant will create hesitation, though it will not banish all hope of finding imperfect coal or lignite.

Such are some of the very important and interesting objects which engage the attention of the geological botanist; we shall next proceed to notice a very few of those equally interesting objects from which the Zoologist will derive a rich treasure of investigation, interest, and pleasure.

Though the Natural Historian has been almost the last to enter on the field of geology, which was at first wholly usurped by the Chemist and Mineralogist, yet the progress and enterprize with which the Zoologist has of late years prosecuted his researches in this domain of extinct life, have placed him at the head of all the cultivators of geological science; so that he has almost driven the chemist, mineralogist, and botanist from the field, and no stratified rock can almost now be identified, as to either age or composition, without his fiat has been pronounced upon it, from the contained organic remains.

It is true, from the *zoophyte*, *medusa*, *producta*, and *trilobite* of the lower grauwacke slate, up to the *mastodon* and recent *mollusks* in the upper tertiary beds, there is spread out such an assemblage and variety of extinct animal life, that the extensiveness and interest of the *fauna* naturally authorize the zoologist to claim a very great superiority and dominion over this kingdom of nature, and to consider many other inquiries subordinate to his researches.

It would be futile in this place to point out even a per-

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centage of the many interesting objects which this department presents to the geologist; whether we look, as we have alluded, at the first forms of organic life in the upper transition rocks and the grauwacke slates, in such genera as the *orthoceratite*, *spirifer* and *producta*, and those species of *mollusca*, which became extinct in the succeeding strata—or in the family of the articulated animals, the *tribolites*, also extinct—or in the star-fishes and coral-lines of the same early period, till we arrive at the vastly accumulated remains of extinct land, fresh and sea-water animals, which are found in the upper tertiary deposits, and which are more or less similar to, and in a multitude of species identical with, those now existing in the waters or on the surface of the earth.

If the naturalist select any of the great kingdoms of nature, whether as a conchologist, an ichthyologist, or as a comparative anatomist, the fossil objects presented to him in either department are, from their variety and repeated novelty, sufficient to attract and occupy his undivided and renewed study and investigation.

It is in this department of the science, that the "wonders of geology" are most conspicuously and strikingly displayed, in the now extensively discovered class of *saurian* reptiles, immense *mollusks* or *ammonites*, and in the large family of gigantic and peculiarly constructed *mammalia*—not to forget the immense fossil kingdom of infusorial organization, disclosed by the microscope, in the structure of chalk, flints, mountain limestone, and many other rocks.

This vast geological *fauna* may be studied only as the "wonders" of the science, without any reference to even the promotion of geological knowledge, properly so called; but when the study of them is connected with the generic or specific strata in which they are found entombed, it leads to some of the most useful and faithful means by which the identification of distant stratifications is established, and

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the successive or corresponding eras of the ancient world are verified. The same lithological structure often occurs, at distant geological intervals, in many of the stratified rocks, so that it is extremely difficult, and even impossible sometimes to distinguish between them; for inorganic matter often presents itself in the same form at different geological eras, from the laws of chemical affinity being permanent and ready to act, whenever circumstances are favourable. Not so animal organization; it is dependant on many more special categories, as locality, food, and climate; and when any set form of it is extinct, it is not found to be renewed; instead of which, life seems to take on new forms and habits, as if a new creative power and action had been instituted.

From different and more restricted characters does the mineral geologist draw his conclusions; for example, in examining a sandstone stratum, he may be in doubt whether to refer its position to the old red series, or to the new sandstone deposit; but the detection of the remains of such fishes, as the *holopticheus* and *amblypterus*, or such zoophytes as *caryophyllia* and *turbinolia*, by the zoological student, will soon resolve all doubt upon the question, and place the rock in the more primitive class. Again, carbonate of lime is found in the form of crystalline limestone, mountain or carboniferous limestone, and in that of chalk and calcareous marl, at great distances from each other in the geological eras of their deposits. These rocks mostly retain their distinctive characters according to the above order; but, sometimes, mountain limestone will assume more or less the whiteness and appearance of chalk, while the latter will put on a greater or less degree of a stony structure and darker hue, which may lead the mere mineralogist to mistake the one for the other, and so make a most serious anachronism in geology. The detection of a *spirifer*, or *producta* in the one rock, or of an *echinus* or an *ammo-*

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nite in the other, will show that the former belongs to the older, and the latter to the more recent deposition of the calcareous earths. Again, the argillaceous deposits of the London clay consist of many mineral ingredients different from those of the sand and freestone of the *calcaire grossier* of the Paris basin, but the resemblance of their organic remains goes far to prove that they were severally deposited about the same period.

The utility of this department of geology, though of the utmost consequence to the science itself—affording, in a great number of instances, the only key by which many problems in the science and in the order of nature's operations can be unlocked; yet it may be said that it extends no farther, and adds little or nothing almost directly to the arts or economic purposes of human life. A knowledge of recent and living zoology contributes much to the subsistence, convenience, and comforts of man, and to the promotion of the arts and the medical sciences; but the whole *fauna* of geology, as far as we are aware, is sterile in all these respects. It is sufficient, however, that it aids so strikingly, usefully, and most interestingly, the study of all parts of the science itself, which have any connection with those vast sedimentary deposits, stratified or amorphous, which cover the greater part of the surface of the earth—and thus indirectly it may be held to be of auxiliary utility to economy and the arts.

We have thus very shortly adverted to a few of the more common objects in geology, which may engage the observation and study of the several students of mineralogy, botany, and zoology, and briefly shown, how in each of these departments, there is a sufficient field to occupy the exclusive attention of any one of them. We need not, therefore, enlarge upon the whole extended empire of natural objects and of the archæological records of a former world, which lies open for the examination and study of him

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who is competently versant with all these three auxiliary sciences—which every one must be, who aspires to cultivate aright the science as it now exists, so as to entitle him to the rank of a finished geologist.

We shall now take notice of a few of those arts and economical uses, to the advancement and benefit of which the science and practical pursuit of geology, more or less, directly contribute; and these are *Mining*, *Agriculture*, *Road Making*, *Architecture*, and the *Chemical Arts*.

Mining.—Of all the useful arts, geology has the most natural and direct connection with the science and art of Mining; for without a knowledge of the stratification of a country—the nature of the rocks—their inclination to each other and the horizon—and the faults and dislocations that may be among them, no successful nor profitable attempt can be made in penetrating the surface in the search of and procurement of minerals.

So far as geologists are acquainted with the mineral deposits of Great Britain, it is found that certain kinds of them are embedded or interspersed only in certain geological positions—denoting distinctive eras of formation or deposition; and except these accompanying rocks are found, it is futile and a wasteful expenditure of money to look for minerals, whether the object be the true metals or coal. Thus, the metalliferous veins of tin and copper are mostly confined to the schistose and micaceous rocks which lie in junction with the granite—the lead and zinc to the upper grauwacke or the mountain limestone; and the bituminous coal to the carboniferous groups of interrupted beds of sandstone, shale, and limestone. It is true that coal is found in the oolitic formation of Yorkshire, and at Brora in Scotland, and anthracite in the grauwacke of Devonshire; but the true bituminous, anthracite, or cannel coal is only found between the old red and the new red sandstone, or in that geological era—however much in many places several of

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the subordinate rocks, as the mountain limestone and the millstone grit, may be thinly interspersed or awanting. Such geological positions do not, however, apply to all other countries in the world; as the bituminous coal is found to rest on granite and covered by the tertiary rocks, in some parts of Virginia; while in Rhode Island and Massachusets, the coal, approaching to pure anthracite, is found to lie between the transition slates and the grauwacke, and to be interrupted by igneous rocks, but is always accompanied by its characteristic fossil plants. The geology, therefore, of any country, it seems, should be studied by itself, to ascertain the true order of stratification of any given area; but a knowledge of the great and general laws of geological superposition will considerably facilitate any inquiry into this subject.

As the plants which are discovered in, and accompany, the coal beds, are found to be nearly of the same genus and even of the same species, whether they are procured from the coal strata of this Island, Germany, North America, India, or of Melville Island, the knowledge of botanical geology will be of great use, any where, in our researches after coal; and the detection, therefore, of any remains of the *calamites*, *sigillaria*, or *stigmaria* in the arenaceous or sandstone rocks, will serve as a most probable clue to the discovery of coal in the neighbouring strata.

The ascertained line of the strike and dip of the strata of the area will necessarily point out the most ready and profitable manner of procuring the coal—whether it can be best worked by an adit, horizontal or gently inclined—or by an upright shaft and by excavations towards the crop or outgoings of the bed, or on the further declination of the strata. The nature of the incumbent rock will give some idea of the necessity or not of providing for arch work and propping; and the superficial dislocation of the strata and its azimuth direction will put the explorer on

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his guard against faults, by which he may regulate his measures for the drainage of the intended mines. Where slips or dislocations may be met with, a knowledge of the relative strata will enable the coal miner to fall again successfully on the bed which has been cut off—whether by seeking for it on a lower or higher level than that of his previous working; and it will be of use to him to examine, whether the coal is more or less bituminous, of the nature of cannel or anthracite, and impregnated or not with pyritical matter—in order that he may be prepared to meet with the several gases, of carbonic acid, carburetted hydrogen, or hydrogen more or less pure.

Acquaintance with local geology is of great use in boring scientifically for coal—in finding out the depth at which it is to be reached from any point on the surface, beneath other rocks or even under the new red sandstone—in ascertaining the dip and strike where not previously known—at what depth porous or sandy strata are to be met with—and the probability of meeting or not with ironstone or limestone, or both, in the same localities.

In the purchase of landed property, with the view of its possibly containing any of the useful metals, the knowledge, to which we above adverted, will inform the inquirer of his chances in this respect; while in the oolitic or cretaceous series of rocks, he will not look for any of these metals.

As it is very probable that the metals in veins are derived from the rocks in which they are contained, the chemical examination of the rocks themselves will aid the geologist in searching for metalliferous veins; and as the direction of a great fault has been found to be associated with a parallelism in the veins or lodes, a knowledge of its direction may lead to the more economical search for the metallic ores. The profitable working of the various kinds of minerals, whether coal or metal, will depend on their situation, the demand for them, the distance of transport,

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all which can only be stated when the special circumstances are known.

Agriculture.—The great utility which the knowledge of the geology of a country affords to the successful prosecution of agriculture and forest planting, is too manifest to be more than alluded to. Many trees and plants, that are subservient to the use and sustenance of man, require very different soils for their better growth and cultivation; and as all soils are but the disintegrated and decomposed materials of the subjacent rocks, mixed with the exuviæ of animals and vegetables, a succinct knowledge of the superficial strata cannot but lead to the more economical culture or adaptation of the surface. By this knowledge it will be ascertained to what kind of trees, or alimentary plants, any given area of country will be best adapted; and, with the additional analysis of the soil, the necessary modes of improving it for certain objects of culture will be pointed out. Thus the pine tribe will grow well where oaks will not, owing to the former thriving in a soil containing far less of the alkalies for their growth than the oaks or the beech require; and potatoes will grow to great perfection where wheat would be a failure, from the latter requiring more silicious with alkaline and phosphatic ingredients in the soil, than the potatoe or any of the leguminous plants do.

Sand, clay, and lime form the principal constituents of the different kinds of soil; and, according as they are afforded in the proper proportions by the disintegration of the subjacent rocks, so will be the resulting productiveness of the land. Pure sand, or pure limestone, alone would form absolutely a barren soil, for argillaceous earths are also necessary to ensure any fertility. Now these latter earths are afforded by granite, gneiss, clay-slate, grauwacke, and the volcanic rocks of basalt, greenstone, and the different kinds of lava. The mountain limestone likewise

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affords very fertile soils, and all aluminous rocks exercise a very fertilizing influence on vegetation from their containing potash and soda. Feldspar and hornblende rocks, by their decomposition, yield, according to the best chemical analysis, a warm and excellent soil. Feldspar contains 17¾ per cent. of potash, albite 11.43 per cent. of soda, mica 3.5 per cent., and zeolite 13.16 per cent. of both alkalies. Basalt contains near 3 per cent. of potash and 5 to 7 per cent. of soda, and clay-slate about 3 per cent. of potash, and loam nearly 4 per cent. of potash. According to Liebig, a single cubic foot of feldspar is sufficient to supply a wood covering a surface of 40,000 square feet with the potash required for five years.* Lands composed of lava, containing argillaceous earths and other disintegrated minerals with sand and chalk, are of the greatest fertility, as is witnessed in the vicinity of Vesuvius and in the reclaimed Island of Ascension. This productiveness is attributed to the alkalies contained in the lava, which, from its successive crumbling and pulverization, affords inexhaustible supplies of these necessary ingredients. The action of the weather will, in time, produce a soil favourable for plants from rocks of granite, grauwacke, mountain limestone, or porphyry, from their containing all the bases of inorganic food in their alkaline ingredients; and, though the land is not at first productive, it may be rendered so by proper arable treatment.

Though a proper application of geology to agriculture depends not on the knowledge of the ages of rocks, but on their mineralogical composition; yet to be acquainted with the order of the rocks and their stratification, with their lines of dip, will be of great advantage to the agriculturist. By this he will be enabled to search for marl, limestone, or clay, if they have not been already discovered, and to apply

* Vide Liebig's Organic Chemistry, p. 143.

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them with the greatest benefit to some other parts of his land that are of a loose, sandy, or silicious nature; by which means adhesiveness will be given to his soils where it is wanted, and dryness to others; and the correction of acidity to other parts, as in any moor or moss land. The order of stratification will also teach the agriculturist, how he can more effectually drain his land, according as any stratum of clay or tenacious rock is at, or near the surface—to penetrate which may be attended with advantage or injury, according as it is above or below an absorbing or porous stratum. The allocation of the strata will also show the sources and causes of any springs of water with which the land may be troubled, if it will not in all cases point out the mode of correcting them; and from a similar knowledge of the inclination of the rocks, a more successful attempt will, at any time, be made to procure water by sinking wells. Though none of the rocks make their appearance at the surface, it will be very important to know whether the strata are horizontal or inclined; for in the former case, the land will be more disposed to be wet, and will with more expense be kept dry; while by opening drains to the surface of the upturned strata, it is probable that a natural drainage may be established between them. From geological deductions, chalk or sand may be reached beneath soils or subsoils of clay or tenacious earth, and thereby the land may be rendered drier and warmer, by the surface water being allowed to percolate through these porous beds.

The proprietor will, in planting, from a knowledge of the geology of his estate, suit the different forest trees to their respective soils—the quality of which in woodland portions, depends very much on the nature of the subjacent rocks. Thus he will find the pine, the spruce, and the larch to thrive better in the clay-slate and grauwacke districts, than the oak, the beech, the ash, or the sycamore,

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which grow better and stronger in argillaceous and in mixed calcareous soils. These latter species of trees not only require more shelter during their early growth, but also, according to M. Liebig and D. Saussure, a much greater proportion of the inorganic ingredients of potash and soda, for the composition of their woody texture and leaves,—the difference being, that those trees, which shed their leaves annually, require five times more alkalies for their constitution than those which are evergreen, as the pine tribe.

The purchaser of land, who is possessed of a competent knowledge of mineral geology, will see his way in the transaction with much more advantage and satisfaction than if he were not. The discovery of a limestone rock or a good building stone, to which he may be led by geological analogies, may be a great advantage where such rocks are scarce in the country; and we need only allude again to what we have said on the more valuable discoveries of metalliferous veins. He may thus also be led to the discovery of beds of coal which lie out of the general line of strike, and which had therefore been either previously overlooked, or that the beds had been thought to have run out, or irretrievably cut off by a fault. The same preparatory knowledge may also afford a clue for the more successful research after a magnesian limestone,—so useful and valuable from its forming a mortar that sets quickly in water, besides its use in agriculture.

Road Making.—A moderate knowledge of the geological structure of a country will be of considerable utility, in laying out and making common turnpike roads or railways, as well as in choosing the rocks with which the roads are to be covered. Where there are porous strata, or hard beds of rocks mixed with softer materials, as shale or sand, the disposition of the strata, as to inclination and strike, will materially influence the choice of the line. If the line of strike is any ways parallel with the sides of a valley, a

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road for whatever purpose will be better projected along that side, where the strata basset out and dip from, than on the opposite side, where they incline to the bed of the valley; for in the former case, the incumbent rock or strata will not be disposed to slip down on the road, which will also be kept free from water, except from what falls in rain on its own surface: while on the opposite course, water will be liable to be continually percolating on the line of road, and the upper strata be disposed to slip down upon it. The two lines of the Manchester and Bolton, and the Manchester and Leeds railways, will illustrate, in one or two localities, very plainly these effects of stratification on the different roads.

A knowledge of the subjacent strata, as to porosity and adhesiveness, whether owing to clay, marl, sand or sandstone, or chalk, will enable the engineer to choose the ground least likely to retain water, or to provide in time by proper drainage for carrying off what the sub-soil will not absorb. The choice of materials for roads is also considerably facilitated by the knowledge of mineral geology. The hardest rocks are not the best fitted for roads, as they generally are brittle and easily broken and pulverized, such as granite and all rocks containing much feldspar, or micaceous lamina. Limestone is nearly as hard, though it is much tougher; but any of the trappean rocks, as greenstone or whinstone, is much superior in every respect; and when a rock of this description can be procured, even though it be at some distance, and at comparatively much more expense, it should be preferred, for it will eventually be the more profitable. What is called the Ganister rock, towards Haslingden, and some of the ferro-argillaceous rocks, containing many vegetable remains, form some of the best materials we have in the south of Lancashire for this purpose, though they are inferior to the calcareous and igneous rocks. The sandstones of our coal measures, except they

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contain a good proportion of calcareous or quartose matter, are little better than a mass of dirty sand, which requires to be scraped off soon after it has been laid on the road. Flints and chert are also good materials where a hard foundation has been previously laid.

The same observations, as we have mentioned above, will nearly apply to the choice of grounds for *Canals.* A geological knowledge of the country, as to its beds of clay, tenacious marl, or porous rocks, will be of great use in determining the line of the canal; for in the one case, the water will be retained, or not so much wasted, as when the canal runs over absorbent or porous strata. In studying the geological surface of a country, with the nature and inclination of the different strata, the engineer will be prepared to meet with the several rocks in succession, so that he may avoid cutting through a retentive clay to a porous rock, or else cut through one of the latter description to arrive at the former, if his levels will permit him. We need not speak of the advantage and eligibility of so projecting a canal, as it may lead through districts in which any coal, limestone, or metallic ores are discovered.

The position of the rocks, their line of strike and of inclination, materially influence the manner and expense of working; so that in all projected excavations, whether for roads or other purposes, as intimate an acquaintance with these geological particulars, as possible, will afford the more correct estimate of a pecuniary outlay.

To the *Architect* or *Builder*, the acquaintance with mineral geology is of very great importance, as the choice of good and durable stones for building depends much on a knowledge of their geological position and mineral composition. Many stones that are hard in the quarry, as those granites in which feldspar abounds, are not the best for exposed buildings, as they are apt to be decomposed by the atmospherical changes from cold to heat, and from dryness

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to moisture; while others that are soft from the quarry and easy to work, become harder when exposed to the air, from the moisture of the stone getting dried up, and also from the greater oxidation of the mineral constituents, or the better carbonization of the lime, which they contain. A stone which, however, contains oxide of iron, should be avoided for public buildings, for though it may be of a uniform colour when first exposed to the air, it will assuredly become stained and rusty. Syenite is more durable than granite itself; compact feldspar and all the trappean rocks are very much so, but the latter of these are disposed to become black from exposure to the atmosphere. Some of the green and whin-stones retain for ages a beautiful bluish or greenish tint, but from the difficulty of working them, they are only used in square or ashler work.

In building the new houses of parliament, great care and research have been taken to have the most durable stone, consistent with a good appearance, selected; and from the survey and examination of many quarries and old buildings, as castles and religious edifices of ancient times, by Mr. De la Beche, a dolomitic limestone from Bolsover, composed chiefly of carbonate of lime and magnesia, in a semi-crystallized state, has been preferred. It is of a light fawn colour, with small vesicles in it like some of the finer oolites. Specimens of this, and of all the rival stones, which may be said to have entered into competition with it, are arranged in the new Museum of Economic Geology in the metropolis.

The mineral geology of any area of a country, and the superposition of the rocks, in any one quarter of it where certain good rocks are found, being known, the engineer will be enabled to examine, with the greater chance of success, those more distant parts where the same useful and desirable rocks may be met with. For instance, the same hard, silicious, and very durable rock, is found in this

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county at Parbold, Whittle Hills, Horrock's Fold, and Fletcher Bank, underlying the great coal beds; and so, the same relative and fixed position is attached to many other rocks, which point out where they will be most likely found, if at all existing in the general area.

A knowledge of local geology will also indicate the most ready and economical manner of opening and working a stratum of rock, and where it is likely to be found in its utmost purity and strength; and in being aware of the constituent lines of stratification and their direction, there will be less chance of confounding them with the lines of cleavage, and so in time, many perplexities and unnecessary operations may be avoided. In these latter instances, the detection of any organic remains lying in a plane, or of a thin seam of shale or clay, will point out the line of true stratification—however cleft and divided the rock may, at first sight, appear to be in any other direction, whether vertical or oblique.

We need scarcely enlarge upon the great uses which a knowledge of the mineral geology of a district enhances, in any proposed preparation of *caustic lime* from its calcareous rocks, whether for the purposes of building or agriculture—in that of *culinary salt*, with the most economy, from either the deposits of brine, or from the crystallized saline rock—in that of *sulphate of magnesia*, so largely used in medicine, from beds of magnesian limestone—in the search after *gypsum* in the most promising beds—and in the manufacture of *alum* from pyritical shales, which so often accompany the coal and lias measures—not to overlook, for the purposes of glass manufacture and that of all pottery and china ware, the different kinds of sand, clay, feldspathic rocks, and even millstone grit, which may be more or less adapted for the relative purposes in view. It is true, that the more direct attention is most profitably applied to the treatment and manipulation of the specific

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article, when or wherever it is procured; but it cannot be denied, that a practical knowledge of geology will be of essential service in pointing out the strata, where the raw material will be, with the most probability, met with, and also the most economical manner by which it may be brought out of the crust of the earth.

Considering, then, the many great and valuable purposes to which a knowledge of geology may be made available, it is to be regretted, that until very lately there has no public encouragement been given, nor any institution erected for the teaching of practical and economical geology in this country—in connection with the support of national or provincial museums—containing, exclusively, specimens of the geological and mineral formations and treasures of the kingdom at large, or of a certain district.

This want, in a national point of view, is being so far remedied by the recent formation of a Museum of Economic Geology, which is now opened in London, under the superintendence of Mr. De la Beche. This museum already contains a great collection of our most important and useful mineral productions—the different native rocks in large cubical specimens, both rough and polished—the different species of British coal also in large regular figures—and there also is a great variety of the best metalliferous specimens from the mines in Cornwall and Wales.*

It would also subserve the great and desirable purposes of provincial knowledge and wealth, if every County in the kingdom had its own museum—containing specimens of every useful and curious rock, of metallic ore, and of organic remains, all properly and intelligibly arranged, that

* Lectures are about to be regularly delivered on Practical and Economic Geology, in the same institution, by Mr. Phillips and others; and it may be noticed, that the University of Durham has also instituted a practical school in connection with a museum on the same useful subject.

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may be found in that particular county. The expense of the erection and maintenance of such a museum at the county town, would be but a fractional charge on the general rate. It would serve to make every inquiring inhabitant acquainted with what his native county contained of the otherwise hidden treasures of nature; as it would serve, from simple inspection, to instruct the foreigner or visiter, in the geological nature and mineral contents of the country over which they were at the time travelling.

To supply, in some measure, this very obvious want in the south of Lancashire, and to promote the taste for the general objects of geology, the Manchester Geological Society has been instituted; and though the Society cannot be expected to fulfil all the more extensive and useful objects of a County Institution, in respect of a Museum, yet from what has alone been published of its proceedings, it may fairly claim the credit of a zealous and sincere endeavour to promote, as far as its means and influence have extended, the study of the science. This the society has especially done with the view to practical and local geology, and the furtherance of all economic knowledge connected with mining,—not forgetting the instruction of the operative himself, by the dedication of funds and otherwise, in the best modes of preserving his life amid the dangers of the mine, arising from the presence and accumulation of explosive or suffocating gases.

In conclusion, we have great confidence in saying, that such provincial societies, when properly supported, will lead to many useful and economical results, besides their becoming the converging points on which the cultivators of the different branches of natural science can meet, to be reciprocally improved, corrected, or enlightened—the facts and discoveries from one science throwing its light across the dazzling or bedimmed atmosphere of another, till

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the object of investigation is illuminated on all sides, and truth becomes more revealed. The knowledge that would otherwise be scattered about in many practical hands, concerning a multitude of things on the earth or under its surface, is thus concentrated, collated, and, if not made, in every case, subservient to some pecuniary interest, it is rendered instructive, and highly useful, by enlarging the boundaries of our ideas, and by improving our mental faculties, in the endeavour to systematize the separated and apparently unconnected facts and phenomena of nature. Much of this can only be done, in any effectual manner, among the members of such societies, who all acknowledge a great body of certain leading facts and principles—forming, what may be called, a common alphabet, without the acquaintance and recognition of which no well understood discussion or comparative reasoning can take place, in order to arrive at any satisfactory conclusion about many of the questions that are continually occurring in this kingdom of nature.

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ART. II.

Sketch of the Geology of Manchester and its Vicinity. By E. W. Binney.

Read 7th of February and 7th of March, 1839.

INTRODUCTORY REMARKS.

The intention of this memoir is to communicate the result of three years' observations, made chiefly on the new red sandstone formation in the neighbourhood of Manchester, and to attempt to deduce therefrom evidence of its relation to the upper coal measures. It is not pretended to give a full and complete description of all the various phenomena of this intricate formation, or satisfactorily to account for their origin; but merely to state what is at present known on this portion of the geology of the neighbourhood, and to direct attention to the more obscure and unknown parts of it. Some of the information furnished to the author, as well as his own observations, may possibly be incorrect; none, however, will rejoice more than himself in seeing any misconceptions or errors, into which he may have fallen, rectified. No one can doubt the propriety of investigating the ground upon which we stand, prior to directing our attention to more distant localities. As a provincial society, the first attention of the members ought to be mainly directed to the examination of the geological structure of their own immediate neighbourhood. Indeed, no course but this is likely to attract the attention of the public, and to shew that Geology is not only valuable as an intellectual pursuit, but that it is one of the most useful of the sciences.

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The geology of Manchester and its vicinity has, perhaps, been less investigated than that of any other large town in the kingdom. This assertion may appear extraordinary, when we consider how much our town owes to the mineral treasures of the earth for its commercial importance; but to all who are conversant with the subject, it will be admitted to be perfectly true.

GENERAL DESCRIPTION OF THE COUNTRY.

Manchester is situated on a part of that extensive deposit of drift, or diluvium, which covers from our view so great a portion of the strata of the midland and north-western counties of England, skirting the sides of the *Penine* chain, and enveloping the lower tracts of country. The appearances presented by this deposit are very variable—at one place it being composed of a coarse gravel; at another of a stiff clay mingled with pebbles; and elsewhere consisting of a fine forest sand. It is only on the great lines of drainage, or in artificial sections, that a view of the substrata is to be obtained. The rock underlying the area of the town of Manchester is the upper new red sandstone—the second member in the descending order of the formation of that name. This formation occupies a considerable part of England, and is chiefly remarkable from its overlying our true coal fields, (most of which disappear under it,) and from its containing those valuable mines of salt and gypsum—for the former of which the neighbouring county of Chester is so famous.

The country to the north-west, north, and east sides of Manchester gradually rises to a considerable elevation above the site of the town; it is traversed by three valleys, along which flow the Irwell, Irk, and Medlock. These three rivers unite at Manchester, and, after a course of ten miles, fall into the Mersey at Irlam Green; thence this river winds its way along the new red sandstone plains of

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South Lancashire and Cheshire, into the Irish Sea. The extent and depth of the valleys, through which these rivers flow, generally indicate the geological features of the country; and it is in them that we find the only true natural sections. Of these valleys, that of the Irwell is by far the most extensive: for the distance of near five miles it is occupied on the south-west side by the carboniferous strata, and on the north-east by the upper new red sandstone. Those of the Irk and Medlock are of much less extent, being chiefly in the vicinity of the town through the coal measures; but whenever they touch upon the new red sandstone, their width visibly increases.

The strata composing the new red sandstone formation, in this neighbourhood, may be conveniently divided into the following (descending) order.

1. The upper red marls.
2. The upper new red sandstone.
3. The red and variegated marls with magnesian limestones.
4. The lower new red sandstone.

The whole of these deposits are very rarely, if ever, seen together; the upper marls having frequently been removed by denudation, and the upper sandstone overlying the two inferior strata. But in one or two places we find the two last entirely wanting, and the upper sandstone resting on the carboniferous strata. To a superficial observer, the only rock occurring in this neighbourhood would appear to be the upper sandstone; the lower marls and lower sandstone being only seen in one or two places at the surface: coal sinkings and borings for water, however, generally prove their existence.

THE UPPER RED MARLS.

This deposit, extending over so great a portion of the neighbouring county of Chester, and reaching to the thick-

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ness of two hundred yards in the salt beds, is seldom to be seen in the south-east of Lancashire. The only place where I have observed it, is on the south of the town, along the line of Oxford-road from All Saints' Church to St. Peter's-square. After going through the diluvial clay ten yards, a thin band of two feet in thickness occurs. In Chepstow-street, leading out of Oxford-road, this bed is between four and five feet thick. In the centre of it occurs a light-coloured layer resembling fullers' earth in appearance, which briskly effervesces when treated with dilute hydrochloric acid. The lower part of the marl becomes arenaceous, and passes gradually into the upper sandstone. Both rocks dip to the west-south-west, at an angle of eight degrees. The marls here found are of a dark red colour, variegated by streaks and patches of green and yellow. They effervesce feebly with acids. No clearly recognized organic remains have been discovered in them. A circular concretion, something resembling the cast of an ammonite, was found in Chepstow-street.

At the meeting of the British Association, held at Liverpool, Captain Portlock exhibited a similar specimen from the new red sandstone of Ireland, and he considered that it was the imperfect cast of an ammonite.

THE UPPER NEW RED SANDSTONE

underlies nearly the whole of Cheshire, and a considerable part of South Lancashire. In treating of it I shall confine myself to a description of its basset edges, without following it upon the dip, except when noticing the thin strips that run into the coal field.

My observations commence at Stockport, where it appears as a fine loose grained red sandstone, much used for moulding purposes. Its general dip is about west-south-west, at angles varying from six to ten degrees with the horizon. The absolute thickness of it is unknown. At

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Edgely, Mr. Sykes bored in it one hundred and seventy yards without passing through it.* In the town of Stockport numerous borings for water have been made to the depth of one hundred yards, which has then been found in sufficient abundance without going further down.† The whole of the valley of the Goyt, up to the point where the Fagg Brook joins that river in Offerton, passes through this deposit.

It runs up the valley of the Tame, past Reddish Mills, to within three hundred yards of Beet Bank Bridge; and wherever the thick covering of diluvium allows its being seen, and its relation to the coal measures examined, they are found to lie unconformably. At Reddish Mills, Mr. Becker has bored in it one hundred and ten yards without passing through it. It extends to Levenshulme, where Mr. Coates penetrated it ninety-eight yards.‡ Near this place it divides into two parts; the main one ranging towards Manchester, and an outlying band, varying from a mile to a mile and a half in breadth, lying between the coal fields of Manchester and those of Denton, Ashton, Oldham, and Middleton.

From Levenshulme the main branch ranges under the Midway House, Longsight Crescent, the Ardwick Toll Bar on the Denton Road, Chancery-lane, (where Mr. Buchan has bored through it eighty-six yards, and Mr. Gallimore eighty-seven yards,) Pin-mill-brow, the Chapel in Every-street, Pollard-street, Canal-street, Bengal-street, Oldham-road, Pump-street, the Gas Station in Gould-street, to Messrs. Clemsons' works, Horrocks, near which last-mentioned place it is seen resting on, and gradually passing downwards into, the red marls. It then passes

* Mr. Hunter, well-sinker, Dantzic-street. † Ibid.
‡ Mr. Bradbury, of Clayton.

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under Red-bank* to Strangeways Brewery, and extends along to Messrs. Lomas and Bradbury's works, where it was found to be ninety-one yards thick, thence under Stony Knolls to Higher Broughton on the banks of the Irwell. At this place it occurs as a pretty coarse conglomerate, and disappears under the diluvial sand of Kersal Moor; but, most probably, extends a considerable distance farther towards the north-east.

Returning to the outlying band at Levenshulme, the western edge of this deposit runs nearly due north, resting on the basset edges of the Manchester coal field, east of Kirkmanshulme, past Belle Vue, Smith House, Smith's bleach works at Openshaw, (where, Mr. Bradbury informs me, it was penetrated one hundred and forty-eight yards,) Clayton, Mr. Wood's works at Bank Bridge, (a little to the east of which the same gentleman bored in it ninety-eight yards,) past the Shears public-house, Newton, and under Harpurhey to Mr. Jonathan Andrew's works in the Smedley valley, and then, probably, under Crumpsall to Broughton. I have obtained no direct evidence of its being found under the first of the two last-named places, but it is generally supposed to be there, though at a considerable depth under a thick covering of diluvium. Indeed, on looking at the points where it is seen in the Smedley Vale, on the north-east, at Mr. Andrew's works, and the lower new red sandstone at Cheetham Vale, to the south-west, nearer Manchester, a distance of not much more than half a mile, and the dip and strike of this rock at Broughton Priory, there can scarce be any doubt of its range in this direction.

The eastern edge is very difficult to trace, but it is

* It most probably runs under Cheetham and Stocks; but the thick covering of drift prevents it from being examined.

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believed to range from Reddish Mills, under Gorton Reservoir, by Fairfield, to a little west of Medlock Vale. Near this last-mentioned place, Mr. Bradbury has found it lying on the red marls. Its direction, then, is considered to be by Newton, west of Moston Colliery, under Prestwich, to the Valley of the Irwell at Giant's Seat, near Ringley; but little evidence, however, is to be obtained of its course by these last-named places.

The Valley of the Irwell, below Broughton, is upon this deposit, which extends from Kersal Moor to near Douglas Mill. Near this place it comes in contact with the Pendleton coal field, and a wedge-shaped mass, resting on its south-west side on the basset edges of the coal measures, runs up the valley to near Giant's Seat Lock, where it terminates. Its south-westerly boundary is the great Irwell coal fault, and its north-easterly part disappears under the diluvium. At Whit-lane, near Douglas Mill, J. Fitzgerald, Esq., in his trial pit, found it one hundred and thirty-one yards thick, and resting upon a thin band of red clay. The boring rods then went into the regular coal measures. Mr. Andrew Ray, who was employed by Mr. Fitzgerald, kindly gave me the result of the sinkings and borings, as follows:

	yds.	ft.	in.	
Sinkings ...	12	0	0	of sand and gravel.
	22	0	0	of upper sandstone.
Borings ...	109	1	4	of ditto.
	0	1	0	of strong red clay.
	30	2	9	of coal measures.
	174	2	1	

The whole thickness of the deposit was not gone through, but the great fault, near which they were boring, and which was inclining towards them, was crossed.

From Douglas Mill this deposit underlies the Valley of

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the Irwell to Salford and Manchester, the whole distance having been proved by boring.* I shall now give a list of the results in searching for water about these towns. The upper sandstone has been perforated at Longsight Hall,† and at Mr. Buchan's, Chancery-lane, eighty-six yards.‡ At Mr. Samuel Green's works, Garratt, that gentleman pierced it one hundred and nine yards without going through it. Messrs. Hoyle, of Mayfield, obtained its thickness one hundred and four yards.‖ The following gentlemen also perforated it—Messrs. Boardman, Oak-street, at ninety-five yards;§ Messrs. Beever, Miller's-lane, about fifty yards;¶ Messrs. Clemson, Horrocks, ten yards;** Messrs. Lomas and Bradbury, Strangeways, ninety-one yards;†† Messrs. Dewhurst, Dawson's-croft, Salford, sixty-yards;‡‡ Messrs. Warmsley and Co., Wheat-hill, bored in it, without going through it, one hundred and fifteen yards;‖‖ Messrs. Rothwell, Water-street, Manchester, one hundred and sixty-four yards: Messrs. Ashton, Broughton Bridge, one hundred and thirty-four yards;§§ Messrs. Henry and James Bury, and Mr. Thomas Bury, each one hundred yards.¶¶ The two first of the last five places are more in the dip than the other places mentioned, and, consequently, the rock there must be of very great thickness. The sandstone is often parted by bands of red clays, varying from several inches to three feet in thickness, known by well-sinkers from their stopping the water in the rock. At Messrs. Dewhursts' a bed was found a yard thick. The same bed occurred sixty yards down in the rock at Messrs. Ashtons'; at Mr. Thomas Bury's a layer, of a similar

* Mr. Tillison, well-sinker.
† Mr. Fletcher, Longsight.
‡ Mr. Bradbury.
‖ Matthew Ward, well-sinker.
§ Mr. Hunter.
¶ Ibid.
** Ibid.
†† Messrs. Lomas and Co.
‡‡ Mr. Tillison.
‖‖ Mr. Warmsley.
§§ Mr. Tillison.
¶¶ Ibid.

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thickness, was met with; but at Messrs. H. and J. Bury's it was only sixteen inches.

The rock then ranges under the south of Pendleton to Eccles; a little to the north of this place a strip of it runs up past Monton towards Worsley, like the outlying bands of Levenshulme and the Valley of the Irwell, before described. Its eastern boundary is not known; but Mr. Lancaster's coal workings, between Patricroft and Monton, prove it to abut against the red marls, the lower sandstone, and the coal measures in the west; whether it reaches Worsley, and joins the main range again, on Chat Moss, is not known. From Eccles the rock skirts the red marls to Mr. Lancaster's engine, where it is seen a few inches thick, overlying the red marls. The dip of all the new red sandstone strata here is in a similar direction and angle to that of the coal measures, and is a little west of south, at an angle of about eight degrees.* Skirting the red marls, it then runs under Chat Moss to Astley, thence to Bedford, Atherton, and Leigh. The whole of the country, in a line from the last-named place to the Manchester and Liverpool railway at Toad Leach, near Sutton, rests upon it. At this last-named place the rock appears to have been separated by the protrusion of the upper fresh-water limestones and superior coal measures through it; it appears again on the railway, near Whiston, and a fault of an exactly similar character occurs there also. Both these dislocations form anticlinal axis; the sandstone at each of them dipping eastwards and westwards, and resting upon the coal measures, in each instance, without the intervention of the red marls and the lower sandstone.

* This was the fact at the rise pit, but at the engine pit it has since unfortunately been proved that, although the members of the new red sandstone were at the same inclination and dip as those at the rise pit, the coal measures were much dislocated by faults, the existence of which the overlying new red sandstone had given no evidence.

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The above being the only instances that I have seen of dislocations in the upper sandstone, and as the red marls and lower sandstone are wanting at both places, I have thought proper to notice them, although lying far from our neighbourhood.

The upper sandstone is composed of fine water-worn grains of white quartz, sometimes mixed with pieces of feldspar, greenstone, and jasper. All these are coloured deep red by a thin coating of per oxide of iron, and slightly cemented together with red clay.* Dr. Dalton estimates the coating of iron to be about one per cent. On being boiled a short time in hydrochloric acid, most of the grains become quite white.

RED AND VARIEGATED MARLS WITH MAGNESIAN LIMESTONES.

These deposits, from their superposition and fossil organic remains, are now clearly proved by geologists to be identical with the magnesian limestones of the north-east of England, although so totally different in character; indeed they form one of the most striking instances hitherto met with of the value of fossils in identifying strata. The limestones are termed magnesian from their position, more than from the fact of their containing that earth, as Dr. Dalton found in a specimen from near Tinker's-brow, exclusive of the iron, about 36 parts of clay, 36 of lime, and 28 of carbonic acid.† It is probable that some of the beds may contain a portion of magnesia, but their precise chemical constituents are, as yet, I believe, unknown.

The marls generally known by the name of "red raddle," and their accompanying limestones, are of very variable thicknesses, as will be seen in the following re-

* Manchester Literary and Philosophical Society's Transactions. Vol. 5, p. 148. † Ibid.

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marks. Generally speaking, (with the exceptions before-mentioned) they have been found under the upper sandstone in all the borings and sinkings in this neighbourhood. Unfortunately they are seldom exposed to view. The only places where they have been seen, except in borings, are Newtown, Monton, Chat Moss, Bedford, and Atherton. They contain an abundance of marine shells (as will hereafter be described) in a most beautiful state of preservation.

In the strip of new red sandstone intervening between the coal fields of Manchester, Denton, Ashton, and Oldham, in Jericho Clough, near Medlock Vale, Mr. Bradbury found them to be fifty-one yards and four inches in thickness, resting on the lower new red sandstone.

At Giant's Seat Lock, in the Valley of the Irwell, a patch of red marls is found dipping under the upper new red sandstone. No organic remains have been found in it; but, from its position and appearance, it is most probably a portion of this deposit.

On the main range of the sandstone they basset out in the Valley of the Irk, at Newtown. They have been found, in boring, at Longsight Hall;* Mr. Buchan's, Chancery-lane, Ardwick;† Messrs. Boardmans', Oak-street; Messrs. Hoyle and Co.'s, Mayfield, fifty-one yards and ten inches thick, containing about ten beds of hard rock, probably limestone; Messrs. Beevers', Miller's-lane, near ninety yards thick;‡ Messrs. Clemsons', Horrocks, eighty yards;‖ Messrs. Dewhurst and Co.'s, Greengate, Salford, seventy yards, containing four thin limestones and a thin gritstone;§ and at Messrs. Lomas and Bradbury's, Strangeways, as follows:¶

* Mr. Fletcher, Longsight. † Mr. Bradbury, Clayton.
‡ Mr. Hunter. ‖ Mr. Vaughan.
§ Mr. Tillison.
¶ Mr. John Leigh kindly furnished me with these notes of borings.

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yds.	ft.	in.	
7	0	0	of soil and gravel.
91	0	0	of red rock.
10	0	0	of dark raddle.
0	1	0	of limestone.
4	0	0	of raddle.
0	1	4	of limestone.
10	0	0	of raddle, containing magnesia?
0	2	6	of light gritstone.
8	0	0	of light raddle.
0	1	6	of light stone.
6	0	0	of light raddle.
1	0	6	of dark gritstone.
139	0	10	

The next place where they have been met with is between Monton Brook and Patricroft, where Mr. Lancaster, in sinking, has found them twelve yards thick, and containing beds of limestone of the aggregate thickness of four feet,* full of similar organic remains to those of Newtown, hereinafter described. They have been proved to extend on the rise and dip about four hundred and fifty yards. Their range is said to be nearly magnetic north; but little is known of its extent. The dip is ten degrees west of south, at an angle of about eight degrees.

They have been found below Worsley, on Chat Moss, and were extensively worked by Mr. Coleby, a little to the north of Bedford. At this place they are about twenty yards thick, and contain ten feet of limestone in twelve beds, parted by thin layers of marl, called by the workmen "Gingerbread."† Their dip is to the south, at an angle of about eight degrees.

* Mr. Lancaster, jun. † Mr. Battersby, Bedford.

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They have been worked at Atherton, but the limestones there are much thinner than at Bedford.

LOWER NEW RED SANDSTONE.

This rock is of extremely variable colour and consistency, at one time presenting the same dark red tint, variegated by patches of a yellowish drab colour, as the upper rock; at another place that of a dirty green. In parts of the same quarry, as at Vauxhall, the upper portion of the rock is composed of coarse globular grains of nearly incoherent red sand, while the lower part is of an extremely fine kind, much used for moulding purposes. Nodules, with thin coatings of rich oxide of iron, occur in the bottom portion. It consists of small pebbles of white quartz, sometimes mixed with fragments of jasper and greenstone, all coloured by oxide of iron, and very slightly cemented together with clay. Generally speaking, it is very much in its component parts like the upper rock, except, perhaps, that its grains are not so thickly coated with oxide of iron, and that pebbles as large as a pea are rarely, if ever, found in it.

Its thickness is extremely variable. It has been always found conformable to the magnesian marls, into which it gradually passes. Where these last strata have been perforated, it has generally occurred. In the strip of new red sandstone lying between the Manchester coal field and that of Denton, Ashton, and Oldham, near Medlock Vale, Mr. Bradbury found it sixteen yards thick, resting on coal measures. In the main range of that deposit, Messrs. Thomas Hoyle and Co., at Mayfield, bored in it twenty yards, and Messrs. Beever penetrated it thirty yards, in Miller's-lane, without going through it.* It is seen outcropping in the Valley of the Irk, at Vauxhall, where it must be near

* Mr. Hunter.

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forty yards thick, and has been found at Messrs. Dewhurst's, Salford, and Messrs. Lomas and Co.'s, Strangeways. Under the magnesian marls, at Patricroft, in Mr. Lancaster's rise shaft, it is only eight yards thick, is of a dirty green, and rests on twenty-five yards of coal measures, under which occurs a yard coal. Its dip is exactly the same as the two superior members of the new red sandstone, and the lower coal measures.*

The limestones of Bedford, I am informed by Mr. Battersby, rest upon this rock, which overlies Mr. Higginson's coals, (a four feet mine and a smaller one,) but its thickness and inclination he was unable to give me.

THE CARBONIFEROUS STRATA.

From the foregoing remarks it must have been seen that the coals of Clayton, Bradford, and Collyhurst, forming what is called the Manchester coal field, are probably an elevated mass entirely surrounded by the new red sandstone: the district lying between Mr. Jonathan Andrew's works, in the Valley of the Irk, near Smedley, and Cheetham Vale, is the only part wherein a doubt can exist. Owing to the thick covering of diluvium, and the want of evidence by borings and sinkings, I am prevented from adducing an absolute proof of the occurrence of the new red sandstone between these two places. There has lately been some other evidence furnished; in sinking a well at Mr. Roylance's residence, in Smedley-lane, which is about midway between the two points, the deep red colour of the coal measures clearly indicated the vicinity of the new red sandstone. However, there can be no question of the upper new red sandstone running up on the eastern side to Mr. J. Andrew's works, near Smedley old mill, from Levenshulme, in a line nearly due north and quietly resting

* Mr. Lancaster, jun.

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on the basset edges of the coals; and that the same deposit skirts the coal measures on their strike through Ardwick and Manchester to near the intended Leeds Railway Station, in Lees-street, Oldham-road. The coal measures are there thrown down by a fault on their rise and dip, which has been proved to be filled with new red sandstone, under St. George's Church and Tinker's-brow to Cheetham Vale. The shape of the field is that of a wedge, having its base at Collyhurst and Smedley, and its point a little north of Levenshulme. That this is the figure of the coal field, as yet known, (in whatever direction the new red sandstone may run,) is abundantly proved by workings and natural sections. It is about three miles and a half long, and one mile broad, at the broadest part. The general dip of the strata is south-south-west, at an inclination of eighteen degrees.

The Pendleton coal field is a part of the great Lancashire deposit, gradually increasing in dimensions as it approaches Ringley on the north-west, and Worsley on the west, up to both which places from Manchester, it is bounded by the new red sandstone formation. Its shape is nearly similar to that of the Manchester coal field. The range of the coals is about north-west; and the Irwell fault runs nearly magnetic north, so that the field gradually extends from the point at Pendleton to the base at Ringley and Worsley. The general inclination of the measures is a little west of south, at an angle of about eighteen degrees. At Monton, Mr. Lancaster's coals, at the rise pit, dip in that direction, at an angle of about eight degrees, similar to the new red sandstone formation there.

THE VALLEY OF THE MEDLOCK.

(See Plate I. *Sec.* 1.*)*

The upper red marls are found resting on the upper new red sandstone at All Saints' Church, and are perfectly con-

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formable to the latter deposit in the amount and direction of their dip. From that place to the chapel in Every-street, the distance is occupied by the upper sandstone, which inclines south-west, at an angle of about ten degrees. From the chapel to the turn in the Medlock, a distance of about two hundred yards, nothing is known of the nature of the strata, but most probably the outcrops of the red marls and the lower red sandstone would be found on searching, as both those deposits have been proved to exist on the dip at Mayfield. At the turn of the river Medlock, below the chapel, are seen several beds of variegated marls, parted by thin bands of gritstone, and containing impressions of a shell resembling the Unio; they dip to the south-south-west, at an angle of eighteen degrees, and are now considered to be the highest part of the carboniferous strata in Lancashire. Succeeding these occur six beds of freshwater limestone, lying intermixed with red clays, fire clays, shales, and fine-grained sandstones, and containing two beds of coal, each about six inches in thickness. The floors of the coals afford the Stigmaria *ficoides*, Calamites, and other coal plants, and a bed of bind above the main limestone yields the Neuropteris *cordata* and most of the other plants of Leebotwood and Uffington, in Shropshire.* The limestones and the coal basses yield a shell similar to that before-mentioned, a Cypris, probably the *inflata*, Microconchus *carbonarius*,† remains of several species of fish of the genera Ctenoptychius, Megalicthys, Diplopterus, Palæoniscus, Platysomus, Diplodus, and large bony rays, resembling those found at Burdic House, in Scotland, as well as many entirely new ones. The thickness of these

* The occurrence of the freshwater limestones, separated by coal measures, and containing the same fossils at such distant points as Ardwick, Uffington, and Leebotwood, is a striking proof of these upper members of the coal field extending under the new red sandstone plain of Cheshire.

† Murchison's Silurian System.

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strata, from the turn in the river to the Beswick Toll Bar, is about one hundred and fifty yards. From the last-named place to the Openshaw coal, (the highest mine that has been worked in this neighbourhood,) it must be near one hundred yards. The Bradford and Clayton mines next succeed here, and seven beds have been worked. Their names are the Charlotte, Three Quarters, Four Feet, Yard, New, Doctor, and Two Feet, mines. These are bounded by a thin grit rock and stone binds, (seen in the river, twenty yards above a garden,) under which are three thin seams of coal, and then occurs the gritstone, on which Mr. Wood's weir, at Bank Bridge, is erected, dipping to the south-south-west at an angle of about twenty degrees: this rock abutting against the upper new red sandstone, to which it is unconformable.

The fault in which the upper sandstone lies, ranges here due north and south. In some places this rock overlies the basset edges of the coals, and in others a bed of stiff red clay, of about a foot in thickness, intervenes between them and the sandstone. This fault is not vertical, but inclines to the east from one foot in two to one in four, the inclination often varying. Great blocks of stone and coal recline on its sides, exhibiting appearances similar to what would be seen on a shelving bank of coal measures lying at the surface. The grit rocks project towards the sandstone further than the shales, forming little terraces, and bear marks of the action of water on a coast line; no fractures or flexures appear in the sandstone to indicate the formation of the fault since its deposition, but, on the contrary, everything shews it to have been long subsequent.* I call the point where the new red sandstone formation abuts against the coal measures, *the fault*, for the exact line of the dis-

* Mr. Bradbury, of Clayton Colliery, a gentleman well known for his sound practical information on mining subjects, has liberally furnished me with this and much other valuable information.

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location in the latter strata we can never hope to determine, since its edges have been worn down and afterwards covered with new red sandstone.

The upper sandstone has been proved by Mr. Bradbury to extend up the valley to near Mr. Otho Hulme's estate, at Medlock Vale. Borings were commenced at Mr. Wood's house, Clayton Vale, where the sandstone was penetrated ninety-eight yards, and they were continued, at intermediate points, to a less depth, beyond Clayton Bridge to Jericho Clough. The sandstone at Clayton Bridge was found to be fifty-nine yards thick, lying upon red marls. On the supposition that it would dip at a similar angle to the coals at Clayton, namely, at eighteen degrees, Mr. Bradbury calculated the rise, and bored again, when, instead of meeting directly with the marls, as he would have done had the sandstone been conformable to the coals at Clayton, it was found thirty yards thick; the next boring proved it nine yards: and further up, in Jericho Clough, adjoining Mr. Hulme's estate, it had cropped out.

Notes by Mr. Bradbury of the borings in Jericho Clough, 1825.

	yds.	ft.	in.
Marl or clay	7	0	0
Sand	4	0	0
Marl	3	0	0
Sand	1	0	0
Strong stony marl	6	1	6
Grey yellowish rock	1	0	0
Red shaly marl with white grit	8	1	6
Soft white rock	0	1	6
Red floor clay	0	1	6
Variegated clays	3	1	6
Whitish limestone	0	0	6
Red shaly measures, which effervesce in acids	8	2	0
White gritstone	0	0	6

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	yds.	ft.	in.
Soft red floor clay	0	1	3
White gypsum?*	0	0	9
Red and white variegated measures	3	2	6
Hard brown rock, containing iron and a little lime	0	2	6
Kind blue shale	0	0	6
White calcareous rock	0	0	9
Soft kind blue measures	3	0	0
Variegated clays	11	2	6
Bastard canky limestone, very hard	1	0	0
Soft red floor clay	0	1	0
Grit rock, full of sharp grains of quartz that rasped the chisel very much	16	0	0
Red floor (soft)	0	1	0
Dirty brown rock mixed with tough clayey dirt, very unlikely for coal	11	1	0
Brown bastard rock	3	0	0
Red clay floor	2	0	0

From these results, the rock dips at an angle of about eight degrees to the south-west. What coal measures these are, it is difficult to say; but from their red clays, (presuming that they have not been coloured from their proximity to the new red sandstone,) they seem most like the upper measures at Beswick. The first outcrop of the coal measures, further up in this valley, is seen in the weir at Waterhouse's, lying in a nearly vertical position. Afterwards, the Fairbottom Company's coals soon come on, which have only a moderate dip.

THE VALLEY OF THE IRK.

(See Plate I. *Sec.* 2.*)*

Proceeding from the Exchange, along the Old Rochdale Road to Newtown, the upper new red sandstone is found

* I believe that this was merely termed gypsum from its white colour.

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underlying the whole distance. Its dip in the river course, opposite Messrs. Clemsons' works, Horrocks, is south-west at an angle of ten degrees. On the northern side of the Irk, near Mr. Worthington's house, this rock is found resting conformably on the red marls, into which it gradually passes. Both deposits incline to the south-west at the angle above-mentioned.

These marls have been chiefly examined on the Newtown side of the river, at the culvert, a little south of the Bull's Head Inn. It was at this place that I and my friend Mr. John Leigh procured the fossil shells which were submitted to the Geological Society of London some years ago. We then erroneously supposed that the deposit was a patch of the upper red marls, and not, as it is now clearly proved to be, the representative of the magnesian limestone, although so vastly different in appearance.

A considerable portion of the deposit must have cropped out before it comes to the culvert, probably near twenty yards. From cuttings which have been made, it appears to consist of a strong red marl.

The beds at the culvert occur in the following (descending) order—

1. A layer of soft clay, of a dull white mixed with streaks and patches of a dirty red, five inches thick, containing no organic remains.

2. Hard red marl of a homogeneous texture, six inches, containing in its middle a single line of shells of the genus Avicula, but they are so fragile that it is nearly impossible to extract them entire.

3. A white calcareous friable paste, resembling fuller's earth, traversed with lines of a beautiful red, arising from decomposed shells, five inches.

4. A light-coloured calcareous band of a soft crumbling nature when first dug up, but it becomes quite hard on exposure to the atmosphere. The upper part of it contains

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an immense number of minute marine shells, the majority of which are broken in pieces; some few, however, occur perfect. Captain Thomas Brown, F.L.S., &c., has been kind enough to figure and describe the following:* Univalves—Rissoa *Leighi*, *pucilla*, and *minutissima*, Turbo *Mancuniensis* and *minutus*, and Natica *minima*. Bivalves —Avicula *inflata*, *discors*, *Binneyi*, and Arca *costata*.

5. An argillaceous deposit of a dark red, having its top and bottom bounded with bands of light-colour, five inches thick. It contains the casts of the Axinus *obscurus*, and those of the three species of Avicula above-mentioned, generally with their valves extended.

6. A hard limestone of a dirty white, four inches thick, containing a great number of casts of all the above shells.

7. Variegated marls, three inches, containing casts (chiefly white) of all the above shells.

8. Dark red laminated marls, occasionally marked by bands and patches of a dirty white. The upper portion of it, to the depth of a foot, is nearly composed of the casts of shells; those of most of the bivalves being extended. In addition to the above-named shells, are Bivalves—Axinus *undatus*, *parvus*, *pucillus*, and *rotundatus*, and Lucina *minimas*. Univalves—Rissoa *Gibsoni* and *Obtusa*. Casts of a circular body, resembling an Echinus, also occur. After going down more than a foot, the shells are seldom found.

Mr. Leigh and myself sunk ten feet into the last-described bed, and then bored twenty-four feet to a hard ferruginous limestone four inches thick. Under this last deposit occur variegated marls and brown shales, which, on the other side of the river, at Worthington's weir, are seen resting on one foot of hard canky grit, under this are

* For description of the fossil shells see Appendix, at the end of this paper.

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three feet of stiff red laminated clays, (full of little circular bodies, resembling the casts of a very small Ammonite,) which become gradually arenaceous, and finally pass into the lower red standstone.

The shells found in these deposits are considered to have belonged to creatures inhabiting salt water, probably a quiet estuary; indeed, the extremely fine particles composing the marls, their laminated structure, and the extended valves of the shells, united as they must have been by a fragile ligament, all indicate a regular and quiet flow of water in a sheltered situation, and very unlike what we should expect to find on a stormy line of coast. The substance of the shell has in most instances been entirely removed, and a cast either in red clay or carbonate of lime, displaying all the minute striæ substituted. The deposit, No. 4, contains the greatest number of fossils retaining a portion of their original shells, but some few have been met with in No. 8.

Many of the animals inhabiting the shells must have been dead at the time of their entombment, as is clearly proved by the open valves; but that they remained long exposed at the bottom of the water seems nearly impossible, as the ligaments uniting the valves would have soon given way, and thereby caused their separation. The *closed* and partially extended valves of the bivalves are generally of a white colour, as are also many of the univalves.

Under all the circumstances, I think we may be allowed to infer that the marls were quickly deposited, as the extended valves and perfect condition of the shells seem to prove. The limestone, however, has every appearance of a much slower deposition; and in it by far the greater number of the shells have been broken into small pieces. Many of the small shells are found quietly lodged in the inside of the larger ones, which could not have been the case had the more powerful inhabitant been alive to

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prevent the intrusion, and which would most certainly not have been attempted, and, in fact, could not have happened under any circumstances until the death and decomposition of the former occupiers.

The marls gradually pass into Mr. Buckley's sand rock at Vauxhall, known by geologists as the lower red sandstone; a deposit which, I believe, is seen in no other natural section in the county of Lancaster. The lines of stratification are very difficult to determine, owing to the number of joints which intersect the rock in several directions, but its general dip, in the opinion of the quarrymen, is west-south-west, at an angle of from sixteen to eighteen degrees. It must also have a considerable inclination to the north-west, as proved by the sinkings at Messrs. Lomas and Co.'s works, at Strangeways, where the lower part of the red marls was found to be near one hundred and forty yards deep as before-mentioned. Under the point called Tinker's-brow, the fault, which has thrown down the coal measures, is crossed, and the lower new red sandstone is seen reposing on strata occurring below the coals at Clayton; these coal measures are partly unconformable to it, and dip ten degrees east of south, at an angle of twenty-four degrees.* From the workings in Mr. Buckley's neighbouring mines, where three of the Clayton coals are worked, it is evident that the coal measures comprising the Manchester coal field have been thrown down in the Valley of the Irk and under Cheetham by a fault, on their rise and dip, in a line running from ten degrees west of south to ten degrees east of north, and that all the before-described members of the new red sandstone have been deposited after the depression of the coals, and that they, in fact, overlie

* The measures at the edge of the fault are probably no fair evidence of the general dip which in Mr. Buckley's collieries is south-south-west, at an angle of eighteen degrees. The strata as they approach Smedley also have a similar dip.

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the whole of the workable portion of the Manchester coal field. After deposition, the members of the new red sandstone group have been raised up by forces which have subsequently elevated the coal measures, as is apparent from the present inclinations of the strata, especially along the edge of this fault.

The measures immediately under the Vauxhall sandstone are succeeded by Mr. Appleton's Collyhurst rock, which rests upon strata containing a ten-inch coal, seen near Smedley Bridge. The thick grit rock of Smedley then occurs. This affords very fine specimens of fossil coniferous wood. Under the Smedley rock a coal, near fifteen inches, has been found at the Old Hall; and betwixt that place and Messrs. Appletons' Paper Mill, a sixteen-inch and a three-feet coal, it is reported, have been discovered.* Beyond this very little more is known of the Valley of the Irk. The fault seen at Bank Bridge is continued across this valley, as is evident from the borings at Mr. Jonathan Andrew's works, where the upper new red sandstone was found. The breadth of this deposit in the valley is not known; it cannot, however, be so wide as I have before proved it to be in the Valley of the Medlock, the Moston colliery clearly indicating its boundary eastwards.

THE VALLEY OF THE IRWELL.

(See Plate I. *Sec.* 3.*)*

The upper new red sandstone is seen inclining at a moderate dip to a little west of south in the quarry at Oatbank, Eccles New Road, and disappears under the diluvium, below Claremont, which then covers the country to the Valley of the Irwell. At the Pendleton colliery, according to the opinion of practical coal miners, the two upper beds now worked there are identical with similar beds in the Clayton

* Mr. Bradbury, overlooker for the Bradford Coal Company.

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and Bradford fields. There are several other seams, all found abutting the upper new red sandstone, in a similar manner to the coals at Bank Bridge, except that the fault is generally steeper.* Their dip is nearly south-south-west, at an angle of eighteen degrees. The depth of this fault is unknown, and will probably ever remain so at this point, although it may be estimated near Ringley. Some suppose it to be a down throw of full one thousand yards. It is filled up and occupied by the upper new red sandstone, which disappears under the diluvium of Kersal Moor, and cannot further be traced in that direction. The dip of the sandstone is south-south-west, at an angle of from eight to twelve degrees. As in the faults at Bank Bridge and in the Valley of the Irk, the coal measures here have been raised up *since*, as well as *before*, the deposition of the sandstone, as is evident from the dip of the latter.

The upper new red sandstone is seen at Patricroft, inclining ten degrees west of south, at an angle of eight degrees.† It bassets out under Mr. Lancaster's engine, and is succeeded by twelve yards of red marls with limestone, and eight yards of lower red sandstone, which last deposit, at the rise pit, is twenty-eight yards above the Yard mine; seventy-five yards farther down the Four Feet mine is found.‡ The coals have, according to Mr. Lancaster's account, exactly a similar inclination as the overlying new red sandstone strata. Both formations are cut off by a vertical fault, which runs in a northwardly direction, and is filled with the upper new red sandstone

* Since this paper was read the workings in the new pits of the Pendleton Coal Company, at a depth of four hundred and eighty-four yards, seem to prove that the inclination of the fault diminishes as you proceed deeper. The chief part of their workings here are under the slope of the fault.

† It was originally intended to have furnished a section of the country from Patricroft to Giant's Seat, Ringley, but from the want of positive evidence on some part of the district, it could not be completed.

‡ This information was given prior to the sinking of the Engine pit.

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as far as it has been proved. Nothing definite is known of the country from Monton to Swinton; so the breadth of the new red sandstone occupying the fault is at present unknown. At Bury Lane, the Three Quarters and Four Feet mines are found dipping ten degrees west of south, at an angle of sixteen degrees. The Clifton mines, as well as Mr. Fletcher's new Three Yards cannel, and the Old Doe coals, have a similar dip. In the Valley of the Irwell, at the turn of the river, near Giant's Seat Lock, the coal measures lying above the Doe coal abut against the upper red sandstone in the Irwell fault. The side of the fault here slopes a little to the east-south-east. The upper sandstone deposited in it appears very thin, and dips at an angle of from ten to twelve degrees, a little west of south. Under this rock occurs a deposit of red and variegated marls (probably the magnesian), seen near Giant's Seat Lock, on the banks of the canal. The lower red sandstone has not yet been observed. Messrs. Brownbill and Co. work the Four Feet mine, and, I believe, a smaller mine has been found above it. At this place, the dip of the coals is nearly south, at an angle of twenty-one degrees. The roof of the four feet coal affords exactly the same remains of fossil fish as those of Bradford and Pendleton.

CONCLUSION.

It will have been seen from the foregoing remarks that the coal measures in this neighbourhood were elevated from the level on which they were originally deposited, prior to the deposition on their edges of the new red sandstone formation. Had this not been the case such a great variation in the inclination of the two formations would not have been found. Undoubtedly the elevation has taken place at several periods, both before and since the deposition of the new red sandstone; the forces producing those elevations

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appear also to have acted in similar directions, as we find the upper new sandstone and the coals generally dipping in nearly the same direction, though at different angles.

On looking at the present coal fields in our neighbourhood, namely, that of Clayton and Bradford, on the one side, of the town of Manchester, and that of Pendleton and Clifton, on the other, it is highly probable that the former was an island, and the latter a peninsula, around which washed the waters that deposited the members of the new red stone. In the former case a strait would have intervened between the Manchester coal field and that of Denton and Oldham, in the other a deep inlet would have separated Whit-lane and the coal field lying beyond Prestwich, while the area now occupied by Red-bank, Newtown, Cheetham, Strangeways, and Broughton, led both to an open sea. In these waters the currents seem to have flowed with very different velocities, as is evident from the coarse grained sand of the lower red sandstone, the comminuted mud of the red marls with limestone, the fine sand mixed with large pebbles of the upper sandstone, and the fine grained silt of the upper red marls. Under the above circumstances, we should expect to find some remains of the former inhabitants of these waters, especially when the conditions appear to have been most favourable for the existence of animal life. Both the sandstones and the upper red marls have as yet afforded few organic remains in England; in the first two we should hardly look for them, as they are very seldom found in deposits of a similar character; but in the latter it is certainly difficult to account for their rare occurrence. However, the limestone and marls of Newtown, and the limestones of Monton and Bedford, yield them abundantly. That the remains are not those of creatures who lived in an open sea, but of the inhabitants of a sheltered bay, is proved by the habits of recent genera of Conchifera and Mollusca now tenanting

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the deep. Thus a strong confirmation is by them afforded of the view before taken of the condition of our neighbourhood after the elevation of the coal measures, and during the deposition of the new red sandstone.

If the facts stated in this paper relative to the new red sandstone formation having been deposited in great dislocations and depressions forming deep bays running both into and over the coal field be correct, there is every reason to believe that coals are to be found under it. The collieries of Monton and Bedford, and the borings at Medlock Vale, clearly prove a fact which has long been known in the eastern coal fields of England, that the mines are in nowise injured by running under the magnesian limestone. The great difficulty is in finding the members of the new red sandstone formation, so thin as to make it prudent for persons to incur the expense of sinking through the deposits which we have seen are so very variable in their thickness. The sandstones also, especially the lower one, are well known to hold immense volumes of water, and when these rocks are of considerable thickness, it is nearly impossible to keep it out of shafts, even by the application of the most expensive metal tubbing. Although, doubtless, a great extent of coal lies beneath the new red sandstone, probably extending from the Lancashire and Cheshire fields under the country to Neston on the Dee, and Leebotwood and Uffington in Shropshire, stored up for future generations, still, under existing circumstances, at the present price of coal, it is extremely doubtful whether, except in some few special instances, coal can be worked to profit under this deposit.

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APPENDIX.

Description, by Captain Brown, of the Fossil Shells found at Newtown.

CLASS I. MOLLUSCA.

1. TURBO MANCUNIENSIS. Plate VI. Fig. 1, 2, 3.

Shell ovate; body large; spire short, consisting of three ventricose volutions separated by a channelled suture; body provided with many prominent, spiral ribs; three on the body above, with five or six concentric ones beneath, and two on each of the volutions of the spire; these are crossed by numerous longitudinal wrinkles; aperture large, orbicular; outer lip expanded, smooth; pillar lip with an oblong umbilicus behind it. Length upwards of a quarter of an inch; body nearly the same in diameter.

2. TURBO MINUTUS. Plate VI. Fig. 4, 5.

Shell slightly ovate, body very large; spire very small, consisting of three abruptly diminishing volutions flattened above, terminating in an obtuse apex, and divided by a somewhat grooved suture; aperture orbicular; outer lip slightly notched on the edge, produced by the projecting ribs; whole shell covered with strong, slightly undulous transverse costæ, two on the superior portion of the body, the lower one so much larger than the others that it produces a carinated appearance; four or five concentric ribs below; base of body flattened, with an umbilicus behind the pillar lip.

3. RISSOA PUCILLA. Plate VI. Fig. 6, 7, 8.

Shell smooth, ovate; body large, inflated; spire short, consisting of three ventricose, deeply divided volutions, terminating in a somewhat obtuse apex; aperture ovate; columella subumbilicate.

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This species differs from the R. Leighi in the volutions being much less oblique, and being only one-sixteenth of an inch in length, and nearly the same in diameter.

4. RISSOA LEIGHI. Plate VI. Fig. 9, 10, 11.

Shell smooth, oblong ovate; spire long, consisting of four deeply divided inflated volutions, terminating in a somewhat obtuse apex; apertnre ovate, slightly contracted above, and rounded at the base; columella subumbilicated. Length one-eighth of an inch; breadth one-fourteenth of an inch.

5. RISSOA MINUTISSIMA. Plate VI. Fig. 12, 13, 14.

Shell smooth, slightly ovate; body very large, ventricose; spire very short, consisting of two abruptly tapering, deeply divided volutions, flattened above, and terminating in an acute apex; aperture nearly orbicular; outer lip smooth, projecting considerably from the body above.

6. RISSOA GIBSONI. Plate VI. Fig. 15, 16, 17.

Shell smooth, oblong-ovate; spire and body of nearly equal length; spire consisting of four not very oblique, but rapidly decreasing volutions, terminating in an acute apex; suture well marked, but not deep; aperture ovate; outer lip smooth. Length not quite a quarter of an inch; breadth somewhat more than one-eighth of an inch.

7. RISSOA OBTUSA. Plate VI. Fig. 19, 20, 21.

Shell ovate, smooth, ventricose; spire nearly equal to the body in length, consisting of three depressed, subturreted volutions, divided by a deep suture; aperture nearly orbicular; pillar lip not reflected, but provided with a slight umbilicus at the base of the columella. Length upwards of a quarter of an inch; diameter not quite so much.

8. NATICA MINIMA. Plate VI. Fig. 22, 23, 24.

Shell ovate; body large; spire small, consisting of two depressed volutions; aperture similunar.

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CLASS II. CONCHIFERA.

9. Avicula inflata. Plate VI. Fig. 25, 26.

Shell smooth, oblique, inflated, transversely oblong-ovate; hinge placed much to one side, where it is narrow and subcompressed, and the auricle small and acute, widening rapidly towards the opposite extremity. Length three-sixteenths of an inch; breadth a quarter of an inch.

10. Avicula Binneyi. Plate VI. Fig. 27.

Shell smooth, oblique, umbones, prominent, acute; superior auricle large, inferior auricle very small; hinge margin straight; posterior extremity abruptly narrowed; anterior side very broad; centre of valves considerably ventricose. Length three-sixteenths of an inch; breadth nearly a quarter of an inch.

11. Avicula discors. Plate VI. Fig. 28.

Shell smooth, oblique; posterior side short, acute; anterior side very broad; superior auricle large; inferior auricle small, parallel with the hinge line; umbones small, prominent. Length a quarter of an inch; breadth nearly three-eighths of an inch.

12. Axinus rotundatus. Plate VI. Fig. 29.

Shell nearly orbicular; umbones almost central, acute, and remote; surface smooth. Length upwards of three-eighths of an inch; breadth nearly half an inch.

13. Axinus parvus. Plate VI. Fig. 30.

Shell smooth, subtriangular, somewhat inflated; umbones prominent, inflated, and contiguous; posterior side acute, oblique, and elongated; anterior side short and rounded. Length upwards of a quarter of an inch; breadth nearly three-eighths of an inch.

14. Axinus undatus. Plate VI. Fig. 31.

Shell subtriangular, smooth, inflated; umbones small, obtuse; sides nearly equal; anterior side rounded; posterior side acute; from the centre of the valve emanates a trian-

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gular flexure, terminating in the baseal margin. Length three-eighths of an inch; breadth half an inch.

15. Axinus pucillus. Plate VI. Fig. 32.

Shell triangular, smooth; umbones very prominent, and nearly central. Length one-eighth of an inch; breadth the same.

16. Lucina minima. Plate VI. Fig. 33.

Shell orbicular, subcompressed, smooth: umbones nearly central, and but slightly produced. Diameter about one-eighth of an inch.

17. Arca costata. Plate VI. Fig. 34, 35.

Shell transverse, oblong-ovate; posterior slope exceedingly short; anterior slope very long; umbones small, and but slightly produced; both valves provided with three prominent ribs, emanating from the umbones, and diverging towards the superior portion of the anterior slope; whole shell covered with irregular, nearly obsolete concentric wrinkles. Length five-sixteenths of an inch; breadth upwards of half an inch.

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ART. III.

Observations on the Lancashire and Cheshire Coal Field, with a Section. By E. W. BINNEY.

Read 31st of October, 1839.

ON looking around us, and observing the numerous manufactories of the town of Manchester and its neighbourhood, and the great population which gains its subsistence from the various branches of the cotton trade, we are led to inquire how such vast effects have been produced. Some attribute the cause to the native industry of the population, aided by a superior genius for inventing machinery. Doubtless both these qualities have greatly assisted, but the main cause arises, not from any living agents, however industrious or skilful, but from the dead earth itself and the invaluable minerals therein deposited by an all-beneficent Creator. The rocks lying under and around us, stored with that most useful and valuable of mineral products, Coal, are the true source of our manufacturing greatness. The streams of water near the town might have afforded some facilities for carrying on the trade, but they are, comparatively speaking, trifling to those which many other neighbourhoods possess; and without the aid of the giant power of steam, Manchester could never have attained that celebrity which it holds throughout the civilized world. Glasgow, Birmingham, Leeds, Sheffield, Wolverhampton, and various other manufacturing towns are situated in the vicinity of valuable coal fields, whence they derive fuel for their numerous steam engines; and they, like ourselves, are

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chiefly indebted to the mineral treasures of the earth for their importance.

Few portions of the earth's surface have benefitted mankind by their mineral products to the extent that the coal field of Lancashire and Cheshire has done. Other districts of England may probably possess fields of greater area, but for richness and position, taking into consideration its number of beds as well as its extent, it is probably inferior to none. Surely the source of so much wealth and power is a subject—the investigation of which ought to interest not only the opulent manufacturer but the humble operative, since both are alike dependent upon it. Why it has attracted so little notice, it is difficult to conceive; yet, certainly, for the extent of its workings, few facts have been collected and arranged. Although the jealousies of coal owners may have prevented them from giving to the public the result of their observations, still the inquirer after truth might have resorted to the fine sections which nature has so profusely exposed to our view in the valleys that traverse the country—sections more to be relied on than those which are so carefully treasured up by some coal proprietors.

It is from natural sections checked by shaft sinkings, kindly furnished by the liberal-minded coal proprietors, that we must for the most part draw our information, until the remainder of that body can be convinced that it is for their own interest, as well as for the general benefit of science, to afford us the facts which their workings have furnished.

The lower boundary of the profitable coal field in Lancashire and Cheshire is generally considered to be the "Rough," or "Quartz," rock that caps so much of the high moorlands in both the counties, and which is well displayed at Parbold in the north-west, and Werneth Low in the south-east. At the latter place it is called the "Old

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Mother" rock. There undoubtedly are some small seams of coal worked between it and the Upper Millstone Grit, as for instance, at Cheesden Bridge, in Shuttleworth, near Rochdale, but seldom to much profit. The upper boundary is often supposed to be the New Red Sandstone, but erroneously; as coals are now worked under it at Patricroft, and no doubt will be in other places. This deposit overlies the coal field, and covers it up, generally resting unconformably on the edges of the higher and sometimes the lower portions, and probably in some instances covering the whole field up from view. It mostly covers the *dip* of the highest measures, and sometimes, as in the cases of great faults in the coal field at Clayton, the Valley of the Irwell, and Monton, covers up and rests upon the *basset edges*. The Fresh Water Limestones of Ardwick and Whiston are the highest portion of it known, and therefore at present may be considered the upper boundary of the field.

Generally speaking, the country is covered by a thick deposit of drift or diluvium, varying from five to eighty yards in depth, and consisting of clay, sand, or gravel. It is of great thickness at Reddish, Ashton-under-Lyne, Whitefield, Kersal Moor, and Bury Lane.

The coal field in Lancashire and Cheshire may be conveniently divided into three portions, as adopted by Mr. Elias Hall in the key to his geological map, namely, the Manchester or Upper Coal Field, the Middle, and the Lower. The first division commences with the Ardwick Limestones, and terminates with the coal measures under Smedley Old Hall, near Manchester, and the intervening strata between the last-named place and the Bardsley Bridge rock* (if any). The middle one with the Bardsley Bridge rock, and ends with the Lower Woodley coal. This

* This rock cannot be identified in the accompanying Section.

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division includes all the thick coals of Poynton, Bench Lane, Ashton, Oldham, Middleton, Heywood, Bury, Radcliffe, Clifton, Worsley, Wigan, and St. Helens. The lower group comprises the strata from the Lower Woodley mine, which is known as the last thick bed, and is identical with the Riley, Dogshaw, and Arley mines of Oldham, Bury, and Wigan, to the Lower Millstone Grit; and contains the coals of Whaley Bridge, New Mills, Mellor, Ludworth, Staleybridge, Rochdale, Todmorden, Birtle, Cheesden Bridge, Newchurch, Quarlton, Bacup, Burnley, Colne, Blackburn, Rivington, and Chorley.

I have, on the assumption that Ellams four feet coal, at Ringley, is the same seam as the Pendleton and Worsley four feet mines, and that these two are identical with the Bradford seam of that name, noticed some of the strata in the accompanying Section as comprised within the Manchester coal field. This is done merely on the resemblance of the respective coals and their roofs, and not from any conclusive evidence of superposition. The dislocations in the upper part of the coal field in the neighbourhood of Manchester, will for ever prevent us availing ourselves of the latter satisfactory proof. The identity of the other coals, when furnished, is given on much better grounds.

I shall now give a slight notice of the coals as exposed in the different valleys in the neighbourhood of Manchester.

Norbury Brook Valley, south of Stockport, affords a good section of some of the middle (Poynton) coals, but their relation with those of the Manchester coal field has not yet been determined. The rivulet on the east side of Lyme Park shews some of the lower seams.

The Valley of the Goyt, from Fogg Brook, in Offerton, to Mellor, displays a fine section of the measures of the inferior portion of the middle and lower coals; the former lying nearly in a vertical position on emerging from under the New Red Sandstone.

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The Valley of the Ethertow affords a view of the lower coals of Compstall Bridge and Ludworth, the rocks and shales of Broadbottom, and the Millstone Grits and Limestone Shale of Tintwistle and Hollins Brook.

The Valley of the Tame, from Reddish Mills, by Arden, Dukinfield, Ashton, Staleybridge, to Saddleworth, shews a good section of the whole coal field, with the exception of the Manchester beds.

The Valley of the Medlock affords an excellent section of the Fresh Water Limestones of Ardwick, and the upper portion of the coal measures known by the name of "The Manchester Field." From Bank Bridge to Waterhouses nothing is known of the coals, owing to their being thrown down by a great fault, and covered up by the New Red Sandstone formation. At Bardsley Bridge, however, the middle part of the coal field is again shewn.

The Irk, at Collyhurst, displays the best section of the three lower members of the New Red Sandstone formation that is to be seen in the north-west of England, as well as a few of the lower portions of the Manchester coal field between Vauxhall and Smedley Old Mill, but the relation of the latter to those of the Oldham and Middleton deposits is unknown.

The Valley of the Irwell, especially that part of it which is between Ringley and Bury, affords the best section of the coal field with which I am acquainted. The strata in many places have been also well proved, by numerous workings in the middle field. In addition to this, the district has been carefully examined for many years by Mr. John Hall, of Mount Pleasant, near Bury, his brother Mr. William Hall, Mr. Robert Holt, of Elton, Messrs. Ramsbottom, of Chesham, Mr. Chadwick, and other practical geologists in that neighbourhood. The first-named gentleman has kindly gone over the country with, and liberally afforded me the result of his observations. It it from his

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labours chiefly, that the accompanying Section has been compiled.

The valuable mines of Oldham, Middleton, Clifton, Worsley, Wigan, and St. Helens are for the most part known by workings, there being but few natural sections in these districts.

The coal field not covered by the New Red Sandstone is seen in its most simple state from Bench Lane, Bredbury, to Werneth Low, where the Bench Lane coals and the Upper New Red Sandstone are within about a mile of the quartz rock in horizontal distance; in its more complex condition, from Patricroft to Pigslee, the same rocks are about ten miles distant.*

This great extension, taken on the rise and dip of the field, is caused by its being traversed with numerous lines of fault running in directions from south and south-east to north and north-west, so causing the beds to occur many times over again. It is from one of these lines of dislocation, namely, from the great Irwell fault at Knob End, near Ringley, that the present Section commences, and continues through Ladyshore, Radcliffe, Bury, Pigslee, Brooksbottom, to Fletcher Bank; due allowances being made for the great faults at Radcliffe, Bury, and Springside, as well as numerous smaller ones.

Although I do not profess to give the exact thicknesses of all the strata in this distance, nor to go into all the details of the various deposits, as thin coals, roofs, and floors, still I conceive it to be a fair approximation to the truth, and present it as an attempt to connect the different parts of our coal field, and shew their relation to each other. The thicknesses of the different strata, where they were not to be ascertained on the exact line of the section, have

* This distance is taken on the rise and dip of the strata, and not on the range, as in the latter direction it is much nearer.

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been procured from workings and natural sections to the right and left of it. Doubtless errors will be found, as is to be expected in an undertaking of this kind, but if the attention of the members of this Society and the public is excited to examine, in detail, the strata of their immediate neighbourhoods, and so to acquire a more correct knowledge of the order of superposition of the rocks and coals, the first step towards constructing a good map of the coal field will have been taken. The coal known by the name of Ellams mine is now generally supposed to be the same as Mr. Knowles' four feet, at Agecroft, and the Worsley four feet, and if so, probably on similar evidence, identical with the four feet of the Manchester coal field. If these hypotheses be true, we have some idea of relative distance between the different portions of the whole field.

Order of superposition of Rocks and Coals from near Ringley to the Upper Millstone Grit of Brooksbottom.

	yds.	ft.	in.	
Shale	6	0	0	Supposed by some to be identical with the Pendleton and Worsley four feet coals, and if so, probably with the Bradford coal of the same name.
Coal	0	2	6	
Shales and Binds, about	30	0	0	
Coal (Ellams mine)	1	2	0	
White Rock with layers of Shale	20	0	0	
Black Stone Roof	0	0	10	
Coal	0	0	9	
Shale	4	0	0	
Coal (Brassy)	0	1	0	
Blue Shale	8	0	0	
Solid Red Rock	45	0	0	
Coal	0	0	9	This rock cannot be identified with the Bardsley Bridge rock.
Grey Folding Rock	15	0	0	
Blue Metal	10	0	0	
Coal	0	1	4	
Stony Shale	20	0	0	

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	yds.	ft.	in.
Coal	0	1	0
Shale	15	0	0
Shale with Ironstone Nodules	2	0	0
Shale and White Earth	16	0	0
Coal	1	0	0
Light-coloured Dirt	1	0	0
Coal (Garbutts mine)	1	0	0
Shale	2	0	0
Brown Rock	2	0	0
Grey Shale with Ironstone Bands	12	0	0
Black Shale	6	0	0
Coal, good 20in., bad 14in., middling 2ft.	1	1	10
Fine White Rock	3	0	0
Strong Metal with layers of Ironstone	30	0	0
Coal, in three folds	0	2	3
Shale with Ironstone Nodules	6	0	0
Red Rock with layers of Blue Shale	12	0	0
Coal 1ft., Dirt 1ft., Coal 4ft. (Five-quarters mine)	2	0	0
Reddish Rock with layers of Shale	20	0	0
Coal	1	0	0
Strong Grey Shale	15	0	0
Coal (Old Doe) in three folds	3	0	0
Blue Shale	16	0	0
Whitish Rock	12	0	0
Coal, good solid (Trencherbone)	2	0	0
White Rock (Ladyshore)	40	0	0
Coal	1	0	0
Metal (not well known)	12	0	0
Coal	0	2	3
Red Rock	10	0	0

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	yds.	ft.	in.	
White Rock	15	0	0	
Light-coloured Shale	15	0	0	
Coal	0	2	0	
Light-coloured Stony Metals	40	0	0	
Coal (Hinds) 5ft. bad	3	1	0	
White and Brown Earth	16	0	0	
Coal	0	1	3	
Light-coloured Metals	20	0	0	
Coal (Gingham mine)	1	1	0	
Floor	2	0	0	
Metal (not well known)	4	0	0	
Red Rock with Shale (Bury Bridge)	35	0	0	
Black Shale	6	0	0	
Coal	0	1	3	
Strong Grey Metals with Ironstone Nodules	9	0	0	
Light Shale with bands of Ironstone	6	0	0	
Coal	0	1	2	
Light-coloured Rock with Red Veins	6	0	0	
Coal	0	0	9	
Rock with beds of Shale (occurs at Cockey Moor, near the Chapel)	20	0	0	This coal is the last thick seam, and identical with the Lower Woodley mine of Dukenfield, the Riley mine of Oldham, and the Arley mine at Wigan. In Harwood it is very thin.
Stony Shale	30	0	0	
White Soapy Earth	11	0	0	
Black Shale	1	2	0	
Clay Vein	0	0	6	
Very Black Stone	0	2	0	
Coal (Lees, or Dogshaw)	1	2	0	
Floor, full of small Ironstone Nodules	1	2	0	

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	yds.	ft.	in.	
Black heavy Stone of a Crystalline structure	1	0	0	This rock is of a red colour at Harwood and Otterscoe Bridge, near Marple.
Blue Shale	6	1	6	
Light-coloured Rock	21	0	0	
White Earthy Shale	60	0	0	
Very Black Shale	30	0	0	
Curled Stone, resembling impure Gannister	0	2	0	It sometimes exceeds twenty yards in thickness, but it is always parted by layers of Shale three or four feet thick. It is worked at Kerridge, near Bollington, Holy Fold in Romilly, Catlow, near Colne, Harwood and Doffcocker, near Bolton, and Enfield, near Accrington.
Light Shale	10	0	0	
Grey Flaggy Rock (Old Lawrence)	6	1	6	
Black Stony Shale	30	0	0	
Black Iridescent Shale, containing Shells of the genera Pecten, Goniatites, &c.	6	0	0	This coal is near eighteen inches thick in the neighbourhood of Bacup.
Coal (Pyritous)	0	1	0	
Black Dirty Shale	12	0	0	
Grey Lumpy Shale	3	1	6	
Brownish Dirty Rock, full of Black streaks	4	1	6	
Hard Sharp Sandstone (Tumbling Cob Rock), well seen at Ending Common, near Whitworth	4	0	0	
Dark Grey Shale, which swells much on exposure to the atmosphere	40	0	0	
Coal	0	0	8	

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	yds.	ft.	in.	
Grey Metals	3	0	0	
White Flaggy Rock, marked with Red streaks and edges	4	1	6	
Dark Shale, containing Shells of the genera Pecten, Goniatites, &c.	5	0	0	The principal mine of Staleybridge, Rochdale, Bacup, Burnley, Blackburn, Halliwell, Darwen, and Chorley. It varies in thickness from five feet eight inches in Dulesgate, Todmorden, to about two inches at Affeside and Harwood, near Bolton.
Coal (Gannister), excellent for Smithy purposes, and often called the "Rabbit" and "Mountain" mine, from the circumstances of its being generally worked by means of levels on the hill sides	0	1	8	
Hard Heavy Stone, full of Stigmaria *ficoides*, excellent material for roads (Gannister)	0	1	2	
Smooth White Clay, sometimes changing into Gannister	0	2	0	
Light-coloured Stone	4	0	0	
Grey Metals	5	0	0	
Black Shale	2	0	0	Principal mine of Quarlton and Affeside.
Coal (Foot mine)	0	2	0	
Soft Brown Stone Floor, containing layers of Ironstone	1	1	0	
Black Shale	15	0	0	
Coal (Bassy), never worked in the neighbourhood of Bury	0	2	3	The chief mine of New Mills, Mellor, Compstall, and Ludworth.
Grey and Brown Shale	6	0	0	
Close Bedded Rock, which divides into Cubes	3	0	0	One of the best building stones in the coal series. This is about its average thickness, but there are
Excellent Light-coloured Building Stone (Woodhead Hill and Lomax Wood Rock)	7	0	0	
Stony Grey Shale	6	0	0	

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	yds.	ft.	in.	
Very Black Shale, containing the Pecten, Goniatites, &c.	14	0	0	instances of its being much thicker.
Coal	0	0	9	
Shale Floor.....	1	0	0	
Coarse Grained Rock.....	8	0	0	Principal mine of Walmersley, Lomax Wood Fecit, and Birtle Dean. The lowest mine worth working in the vicinity of Bury.
Dark Shale, full of the Pecten, Posidonia, and Goniatites, mixed with Ferns, Lepidodendra, &c.	0	1	6	
Coal (Featheredge)	0	2	3	
Rough, or Quartz Rock, full of large rounded Quartz Pebbles..	12	0	0	This rock is often taken for one of the Millstone Grits. It is exposed at Wibbersley, Werneth Low, Blackstone Edge, Birtle Moor, Pilsworth, Turton Tower, Horwich Moor, Holcome, and Parbold.
Grey Stony Shale, often approaching to Flags.....	25	0	0	Rowley Moor, Summit, and near Whitworth.
Rough Flaggy Rock, provincially termed "Rag"	4	0	0	
Fine Smooth Flags.....	2	0	0	
Strong Brown Stone, parted with Shale, containing thin beds of Flags	50	0	0	
Fine Grained Rock, of a Bluish colour	2	0	0	
Grey Shale	8	0	0	

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	yds.	ft.	in.	
Black Shales (Pecten, &c.)	37	0	0	Cheesden Bridge, Sunnyside, below Holcome Hill, Brooksbottom, and Summit Tunnel.
Coal	0	0	6	
Black Shale	2	0	0	
Coal	0	0	8	
Black Shale	8	0	0	
Black Shale with layers of Stone	6	0	0	
Coal	0	1	3	
Dark Shale	4	0	0	
Upper Millstone Grit of Brooksbottom, Holcome Brook, &c...	unknown			

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ART. IV.

Remarks on the Marine Shells found in the Lancashire Coal Field. *By* E. W. BINNEY.

Read 26th of March, 1840.

As the relation which the Carboniferous strata of Lancashire bear to those of the County of York, is a subject likely to occupy the attention of the members of this Society in the projected section across the *Penine* chain, a short notice of the organic remains found in the deposits occupying the lower parts of the respective fields will probably not be found uninteresting. In this communication it is intended to confine the remarks to fossil shells, without noticing the plants; and to point out the localities and position of those which have generally been considered by geologists to be of marine origin, and where they are succeeded by those supposed to have inhabited fresh water; without describing their generic and specific characters.

Professor Phillips, in his treatise on geology in the Encyclopædia Metropolitana, at page 590, speaking of the lower coals, states that "this portion of the series resting upon the Millstone Grit produces comparatively but a small quantity of coal, and this not in general of a good quality; but no part of the coal field is more curious in its geological relations, or more worthy of close study by those who desire to penetrate into the history of the production of Coal.

"We may define this lowest series very simply, by saying that it is included between the Millstone Grit beneath and the Flagstone rock above; having a thickness about one hundred and twenty or one hundred and fifty yards, and

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enclosing, near the bottom, two thin seams of coal, one or both of them workable, and several other layers, scattered through its mass, too thin to be worth working.

"The most regular and continuous of these coal seams reaches in a few places to the thickness of twenty-seven or thirty inches, and it is worked at Yeadon, Rawdon, and Horsforth, near Leeds; at Baildon and Heaton, near Bradford; at Catherine Slack and Swan Banks, near Halifax; at Bull Houses, near Penistone, and at several points west of Sheffield. It would have been impossible to have traced so thin a seam of coal along so extensive a range without some peculiar facilities, some points of reference more distinct than the varying quality of the coal, and the still more irregular fluctuations of the sandstones and shales. This seam is covered by a roof unlike that of any other coal bed above the Mountain Limestone in the British Islands; for, instead of containing only the remains of plants or fresh water shells, it is filled with a considerable diversity of *marine shells* belonging to the genera *Pecten*, and *Ammonites*; and in one locality specimens of *Orthoceras*, *Posidonia*, and scaly fishes have been obtained from certain nodular concretions, called 'baum posts,' lying in it.

"The uniform occurrence of these *Pectens* and *Ammonites* through so wide a range, over one particular thin bed of coal, and in no other part of the coal strata, is one of the most curious phenomena yet observed concerning the distribution of organic remains, and will, undoubtedly, be found of the highest importance in all inferences concerning the circumstances which attended the production of Coal.

"In this part of the coal system we may observe, besides the very remarkable layer of marine shells, several occurrences of a peculiar hard silicious sandstone called Galliard, Gannister, Seatstone, &c., which, in fact, is the same thing as the Crowstone in the Mountain Limestone series of Swaledale. This stone sometimes forms the floor or sill of the

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coal, a circumstance never observed in the upper coal strata; amongst which Galliard never occurs in its true character; hence the whole group may be appropriately termed the Gannister coal series.

"The Ammonites and Pectens which lie above one of the seams of coal, and still more the Orthocerata, which sometimes accompany them, are remarkably analogous, and, perhaps, in part identical with the fossils of the Mountain Limestone. The Galliard is likewise to be compared to similar stones in the Mountain Limestone series, and therefore the Gannister coal series might, with much propriety, be associated with the upper Mountain Limestone series of the Penine chain, or with the Millstone Grit series of Derbyshire, and thus the Flagstone would appear to be the lower limit of the true coal measures. An examination, however, of the neighbourhood of Halifax has shown another order of phenomena, and another set of shells, which connect this same series with the upper or true coal measures. In the upper coal series of the Northumberland, Derbyshire, and Yorkshire, are several layers of bivalve shells, commonly referred to the genus *Unio*, from which the freshwater origin of these deposits has been inferred. In the midst of this series of Gannister coals, two layers of these shells occur; one of them about the middle of the series, considerably *above the Pecten* coal, and the other near the bottom, and considerably *below that coal*."

Mr. Teale, in his paper on the fossil Icthyology of the Yorkshire coal field, read at the meeting of the Geological and Polytechnic Society of the West Riding of the County of York, held at Leeds on the 5th day of December, 1839, in speaking of the identity of a black earthy looking substance found at Moortown, near Leeds, with the coals at Halifax, says, "how are we to know their identity? Their appearance, or, in other words, their physical characters do not enable us thus to decide. It is by their being accom-

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panied by a particular fossil, the Pecten *papyraceus*, which is now known to be characteristic of this bed. The shale which forms the roof of the Halifax coal is crowded with this elegant fossil, and by means of this shell may be traced, overlying the black earth of Moortown, the impure coal of Kirkstall Wood, and the progressively improving coal of Idle, Bradford, and Halifax. All fossils are not, however, of equal value for the purposes of identification. The Pecten *papyraceus* is of great importance in this respect; for, although occurring extensively in the Mountain Limestone formation, it is only known to prevail in the Yorkshire coal measures, in the single bed of shale which forms the roof of the Halifax coal; on the contrary, other fossils, as the Unio *acutus* and Unio *subconstrictus* may have so wide a distribution as to be of little diagnostic value."

Having thus stated the opinions of the above-named geologists on the fossil shells of the lower portion of the Yorkshire coal field, I shall now proceed to notice the information which has been given to the public respecting their occurrence in the Lancashire coal field. The only author that I am aware of who has noticed them is Mr. Francis Looney, F. G. S. In describing the fossils found in and near the Gorsehall Rock, in Mr. Elias Hall's Key to his Geological map, Mr. Looney states, "under this rock (the Gorsehall) there is a small one foot coal, and further down a small two feet seam, known by the name of the "Mountain Mine," between which two coals the only marine shells of our formation are found. The shale over the one foot has the Pecten *papyraceus* and Pecten *dissimilis;* and in the shales underneath, in nodules of Ironstone Ammonites (Goniatites) *Listeri*, *reticulatus* (Bean), *Looneyi* (Bean) *subcrenatus? sphericus?* Orthoceras *cylindraceus*, *attenuatus*, *sulcatus*, Turritella, with several other unfigural shells of various genera. There is little doubt but that all the

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species of marine shells named in the list given by Mr. De la Beche, (Manual, page 758) may be discovered by due attention." The coals here alluded to by Mr. Looney are the Forty yards and Gannister mines of Rochdale and Burnley, and the locality where the fossils occur, the black shale over the small coal, under which the fire clay is worked at Staleybridge. Mr. Samuel Gibson has found in the black shales, near Hebden Bridge, the greatest number of marine shells that have hitherto been described; but not knowing the precise locality from which they have been obtained, or the exact position which they occupy in the carboniferous strata, I shall pass over them without further notice.

Before describing the localities in which I have met with the Pecten, Goniatites, and other shells, generally supposed to be of marine origin, it will be necessary slightly to notice the strata lying between the Carboniferous Limestone and the lowest deposit in which these fossils have been found in our coal field.

The deposits generally known by the name of Limestone Shale and the Millstone Grits, are not often met with in the counties of Lancaster and Chester. The only places where I have observed the first-named deposit are in the Vale of Todmorden, and at the lower part of Pendle Hill,* at the former place their thickness is very difficult to estimate, but at the latter it must be near two hundred yards, consisting of black and dark brown shales, parted by bands of Gritstone, one of which, in the lower portion, as seen in the quarry above the Limestone in the brook flowing from the side of Pendle Hill to Twisden, is five yards thick. Marine shells, in greater or less abundance, are found

* Since this paper was read, I have observed them at Hollins Brook and Tintwistle, near Mottram.

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throughout the whole of the lower shales at this place. Amongst these fossils, however, I did not recognize either the Pecten or Goniatites.

The Lower Millstone Grit is the next rock in the ascending series. It consists of a coarse grained sandstone full of quartz pebbles, and often containing feldspar. It is a remarkably compact stone. The thickness of it has never been correctly ascertained; but at Barley, near Pendle Hill, and Gauxholme, near Todmorden, it is probably about seventy yards. This amount includes the Flaggy Rock lying between the Limestone Shales and the compact bed which has often been worked for Millstones, and from whence the name was derived. The flaggy deposit is well shown on the side of Pendle Hill. This rock is also seen at Roecross and Tintwistle, in Mottram en Longdendale. Immediately above the Millstone bed is a deposit of dark coloured shales, reaching nearly to the thickness of sixty-five yards, which contain two small seams of Coal, one of ten inches, seen in the brook near Halliwells Mill, in Dulesgate, Todmorden, and the other of six inches, a little higher up, appearing on the side of the road there leading from Todmorden to Bacup. In the measures adjoining these coals I have not yet been able to detect the marine or any other shells, though it is extremely probable that they are to be met with on diligent search.

The Upper Millstone Grit is not so solid and compact a rock, and is generally of a finer texture than the lower, and is often divided by partings of shale. It is exposed in Dulesgate, Todmorden, at Brooksbottom, near Holcome, and Fletcher Bank, near Bury. At New Church, in Pendle, its thickness cannot be short of sixty yards; but as it has seldom been sunk through, or bored into, it is difficult to estimate. Immediately above this rock occurs a group of fine shales of a dark black colour, containing generally

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three thin beds of coal, the lower of which is worked at Cheesden Bridge, in Shuttleworth, where it is about eighteen inches thick. Near Sunnyside, at Brooksbottom, and at the foot of Holcome Hill, these shales and coals are found, and contain an abundance of shells of the genera Pecten, Goniatites, Posidonia, &c., together with the scales of a fish resembling the Diplopterus. But the locality where they have been chiefly exposed has been in the cutting of the Summit Tunnel on the Leeds Railway. On commencing the south entrance of the tunnel, they occurred immediately under the Great Flag rock, and were found in all the shafts to No. 7, where the Upper Millstone Grit was reached. The tunnel running nearly north and south, which is about the line of the rise and dip of the strata, is for the most part in them. These shales, as well as the nodules of Ironstone found in them, from the lowest to the highest beds, yield an abundance of the Pecten, Goniatites, Posidonia, Nautilus, and numerous other marine shells, but no traces of the Unio, or any other reputed fresh water shell, have yet been discovered in them. There is, however, in a dark grey micaceous shale, lying immediately above the Upper Millstone Grit, a bivalve partly resembling the Unio, still, from its occurring in company with the Nautilus *carinatus*, there can scarcely be a doubt as to its marine origin. These strata are identical with those at Swan Banks, near Halifax, (supposing the latter to be immediately above the Upper Millstone Grit Rock,) where Professor Phillips found the marine shells lying between two beds of the Unio. Whatever specimens of this fresh water shell may have been found at Halifax, certainly none have been as yet met with in forming the tunnel.

The next ascending strata are Shales and Gritstones, generally known by the name of the "Haslingden flags," in Lancashire, and the "Elland flags," in Yorkshire. These pass upwards into the Rough rock, so named from its coarse-

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grained texture, which is very much like the Lower Millstone Grit. No traces of shells of any kind have as yet been recognized in these extensive deposits. Owing to the absence of any beds of coal in them worth working, they have not been much examined; so they probably may exist without having been discovered.

Immediately above the "Rough rock," at Birtle Dean, near Heywood, is the Featheredge coal, about two feet thick; this seam has a roof of one yard in thickness, consisting of black shale, which is full of the Pecten, Goniatites, Posidonia, &c., mixed with various species of Ferns, Lepidodendra, and Sigillariæ. It is a singular fact that the black shale has scarcely ever been seen on the roof of this coal, except at Messrs. Ramsbottom's colliery, at Birtle Dean. At Fecit, within two miles of the last-named place, and other localities, the roof of the coal consists of a coarse conglomerate of quartz pebbles, containing numerous garnets and crystals of Carbonate of Barytes generally presenting a waterworn appearance. I have also observed small pieces of Opal imbedded in this rock.

At a distance of ten yards above the Featheredge coal is a little coal of ten inches, having a roof of black shale full of the Pecten and Goniatites. Amongst other places these fossils are found in the brook, near a place called Barlow's o'th Coal Pits, in Pilsworth, by the side of the Turnpike road, about half way between Bury and Middleton.

The Rochdale or Gannister coal lying at Birtle Dean, about sixty-five yards above the last-named mine, affords, at Mr. Dearden's colliery, in Dulesgate, Todmorden, the Pecten, Goniatites, Posidonia, &c. They also occur at Colonel Hargreave's pits, near Colne; the places where they are found are the black shales and the Ironstone nodules lying above the coal. The Goniatites, at the latter place, are highly pyritized, and in a beautiful state of preservation.

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In Dulesgate, a thin workable seam of coal, having a black shale roof, lying seventy-three yards above the Gannister coal, and identical with the Forty yards coal, at Rochdale, affords the Pecten. At Staleybridge, in the black shale forming the roof of a small coal, under which is worked a fire clay, sixty-seven yards two feet above the Gannister coal, (there known by the name of the Parron Mine,) the same shell with many others occur. These are the highest strata in the coal measures in which the marine shells have yet been found. The strata from this point to the Lees or Dogshaw Mine of Bury and Heywood consist, for the most part, of very black shales having several grit rocks lying in them. The thickness is full one hundred and seventy-three yards, and from its remarkable barrenness in yielding coal, has been very little examined.

Near Heywood, in Bamford, at a place called Simpson Clough, the outcrop of the Dogshaw or Lees coal is seen, and in the black shales, extending about ten yards under it, are plenty of the large Unio, and that species known by the name of the *acutus;* so that here we have the first evidence yet discovered in the ascending series of fresh water shells in our coal strata. Where the exact line of boundary between the fresh water and salt water deposits occur, I have not yet been able to discover; although I have examined the measures in the brook course from Simpson Clough all the way to Birtle Dean, where the forty yards coal is worked, a distance of above two miles.

After observing the facts contained in this paper, I have come to the following conclusions:—

1st. That whatever may be the case in Yorkshire, the occurrence of the *Pecten*, *Goniatites*, and other acknowledged marine shells do not indicate one particular seam of coal in Lancashire, but that they are found over five distinct beds.

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2nd. That hitherto no bed of the *Unio*, or any other shells of fresh water origin, have been found in our coal field lying between or amongst those beds in which the *Pecten*, &c., occur.

3rd. That the marine shells have been traced to within one hundred and sixty-three yards of the first bed of the *Unio* in the coal measures.

4th. That the change from marine to fresh water deposits is within one hundred and seventy-three yards of the Lees or Dogshaw coal, and appears to have been effected without great local disturbance, as the fine grained shales seem to indicate.

5th. That the strata in this distance are some of the most barren of coal in the whole series.

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ART. V.

On the Origin of Coal; and the Geological Conditions under which it was Produced. By J. E. BOWMAN, F.G.S. & F.L.S.

Read 30th January, 1840.

To trace the operations of Nature in periods not only long anterior to all human records, but to the very creation of our species; to pronounce opinions respecting the structure of the globe on which we dwell during the progress of its formation, and of the successive changes necessary to fit it for the reception of organized and sentient beings, may appear at first sight to be presumptuous and beyond the reach of our limited and feeble powers. But since it is the high and exclusive privilege of man to be endowed with observation and reflection, and feeling that it is a primary law of his nature, that in proportion to the active and legitimate employment of those faculties he becomes useful to others and happy in himself, it would indeed be strange if he could resist the impulse to exercise them on the grand and beautiful in nature which are every where so profusely scattered around him. Such studies, far from being, as some timid minds have superficially supposed, hostile to Religion, are in fact, its best auxiliaries, by enlarging his conceptions of the Great Author of all things, and habitually leading him to refer every thing he sees to His power and benevolence. Nor when he scales the precipitous rock, or descends into the mine, will he fail to witness in the imbedded fossils, various forms of organic life, now extinct, but which, in form, texture, and general character, abundantly prove that

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the same great physical laws, the same harmony, and the same wisdom and design which still pervade and controul universal nature, then existed. These facts irresistibly lead him to penetrate in imagination, into those inconceivably remote epochs which his finite faculties can never fully estimate, and to trace in the mighty convulsions which then agitated its interior, the causes which have produced the existing conditions of the surface of our planet. To whatever geological formation he may direct his attention, he will not fail to be convinced that while all was yet without form and void, a Divine intelligence was controuling and modifying the elements, and preparing the earth to be a fit receptacle for its future inhabitants. While the successive orders of animated beings, however low in the scale of sentient existence, were endowed with an organization best adapted to their several situations and wants, they were unconsciously contributing in various ways, in life or after death, to bring about the designed end. The luxuriant vegetables and forests that covered the primœval land, seem to have had almost exclusively a prospective use; for they flourished in an atmosphere which, from its impurity no animal could probably have breathed, and long before intellectual man was introduced into this beautiful world to be charmed with their rich magnificence, and to wonder at their grotesque peculiar forms. Successive generations of these plants flourished and decayed without being of any apparent use; were sunk beneath the waters and entombed under the bed of the ocean. There they were slowly converted into Coal, and after a lapse of countless thousands of years, were again thrown, by other revolutions, upon or near the surface, and extracted by the intelligence and industry of man, to minister in so many ways, to his wants, his comforts, and his luxuries. If we take into account that along with these precious beds of fossil fuel, are generally associated immense deposits of iron ore, which, without the coal,

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would to a great extent be useless, I think we must admit that they collectively present one of the most striking instances of prospective design and benevolence exercised for the benefit of man at an incalculably remote period before he was called into existence.

The great commercial importance of fossil Coal, and the obscurity that, it must be confessed, still hangs over a portion of its history, have induced me to direct attention to some views which are probably new to many, and indeed are still far from being yet generally received by geologists themselves. The subject naturally divides itself into two distinct parts; The Origin of Coal; and the Geological Conditions under which it has been Produced.

1st. As to the Origin of Coal.

Those whose recollections upon the subject extend back but a few years, are aware how little was then actually known, and how unsatisfactory were the conjectures as to the substance from which Coal was derived. But the experiments of Dr. MacCulloch following those of Hatchett and other previous investigators, have since so satisfactorily proved its vegetable origin, that I shall only need to touch briefly on this division of my subject.

In the ordinary process of vegetable putrefaction and destruction, a variety of compound gases are formed by the reaction of their elements, and carbon alone, or rather carbon united to a portion of hydrogen, remains behind. The experiments just alluded to are in perfect harmony with this natural process, and have proved the following facts: That all vegetables, including wood, are chiefly composed of oxygen, hydrogen, and carbon; that in Peat, which is the first or incipient stage of their decay produced by the action of water, the two latter elements form a hydro-carbonaceous compound, which communicates its brown colour to water; that peat itself does not appear to contain any bitumen, but that this latter substance in some of its modifications, as

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alphaltum, mineral tar, oil, or naphtha, is generated by the slow conversion and formation of the hydro-carbonaceous compound under pressure, during which the complete separation of the hydrogen from the carbon takes place, and the consolidation of the latter is completed; this however is a slow process, and a lengthened time is necessary to complete it. That bituminized wood, Surturbrand, Bovey Coal, &c., as well as vegetables and Peat, contain hydrogen and carbon, and in greater proportion according to the degree of closeness and pressure to which they have been subjected under beds of soil, clay, &c.; that a sufficient length of time being allowed, mere pressure and exclusion from the atmosphere are sufficient to convert bituminized peat and lignite into coal; and lastly, that the action of air and water on vegetable substances is similar to that of fire, though much slower and less complete.

Those who have paid attention to the formation of peat at the present day, are aware how closely in some of its more perfect states it approaches to coal; but as its different appearances may not be generally known, and will materially help us to understand how those vast depositories of fossil wealth were originally accumulated, a short notice of its growth and subsequent changes may be advantageously introduced. A variety of our native plants, such as Mosses, Cottongrass, Rushes, Segs, Coarse Grasses, Ferns, Heather or Ling, &c., &c., chiefly natives of moist situations, enter into the composition of peat. In addition to the spongy texture of many of these, which enables them to arrest and retain the water around them, the mosses especially possess this peculiarity, as the root and lower extremity die and are decomposed, the part immediately beneath the surface, sends out fresh roots, the individual thus as it were becoming perennial, lengthening upwards, as the surface of the bog rises, while the lower and older portion decays, and furnishes a perpetual supply of decomposing vegetable

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matter. A similar process takes place in many of the rushes and grasses, the original roots and lower leaves dying, while an annual renovation of both continues the existence of the plant upwards. This indeed is on their part but an effort of nature to escape being smothered by the thick and swelling beds of surrounding mosses, just as trees in a dense plantation shoot rapidly upwards, because their tops are the only part that light has access to, and loose their leaves and lower branches wherever that important element is excluded. In some Scotch peat bogs, Cottongrass (Eriophorum vaginatum) has been traced in an organized state to a depth of four feet beneath the surface, with numerous distinct tufts of roots one above another, the lowest or oldest being in a state of the greatest decay, and the highest or last formed, alone ministering to the growth of the plant. In these the gradation downwards from the living vegetable to compact inorganic peat, is often easily traced. Above, where the living plant is in contact with the surface, the roots are fresh and healthy; lower down they are found vaccillating between life and death in a spongy half decomposed mass, and the pulverized carbonaceous matter is soon mixed with similar fibres still resisting decomposition. Proceeding downwards, these gradually disappear, till at length a black smooth semifluid substance alone is found, the process being completed by the total destruction of all the organized fibres. In the deep peat bogs of the Hebrides, the lowest part is in this state of extreme decomposition, and its specific gravity is much greater than that of ordinary peat. When dried it burns with so bright a flame as to supercede the necessity of candles in the cottages of the poor, and with a glow of heat equal to that of the inferior kinds of coal; while it is capable of being formed into a compact charcoal fit for the purposes of the blacksmith.

This peculiar structure of the plants and annual rise of the roots, naturally cause a very rapid increase in the thick-

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ness of the beds in which they grow. It is on record that some peat bogs in Scotland have been formed on fallen forests in the short space of fifty or sixty years; in Germany, cavities of seven feet deep have been filled with peat in thirty years. These however are extraordinary instances of rapidity beyond its usual rate of formation, which varies according to the humidity of the subsoil, the nature of the vegetation, and the warmth and moisture of the climate. It is important to bear these conditions in mind, because when we come to treat of the ancient vegetation which has formed the coal, it will naturally help us to comprehend, how, under the infinitely more favourable circumstances of a hotter climate and more humid atmosphere, those grotesque prototypes of our puny plants have acquired their gigantic dimensions—dimensions probably in many instances as much exceeding those of the plants now inhabiting the tropics, as the latter do the vegetables of an arctic climate.

It is well known that peat bogs such as those of our own island, are confined to temperate and cold latitudes, and that as we approach tropical regions, they become fewer and disappear altogether. From this circumstance an argument has been raised that Coal could not have originated from peat bogs, because at the time of its formation, the climate of this country was at least as hot as it now is between the tropics. This only holds with respect to the dissimilarity of the species, for as all plants, of whatever size and habit, are composed of the same elements; and as it is well known that their growth in the rank savannahs of the torrid zone is much more luxuriant and rapid than in cold countries, there is sufficient analogy to justify the comparison. It is not contended that our peat bogs would ever produce solid coal, because no conditions in the present state of the earth's surface can ever resemble those of the carboniferous period as to climate and internal heat, and the submersion and pressure to which the ancient beds were sub-

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jected. Neither would the vegetation of a modern tropical forest; but the experiments of chemists show the gradual process of the bituminization of decomposed vegetable matter, and that the more complete the process, the harder and more insoluble is the coal; while the great abundance of fossil plants among the beds, and above all, the carbonization of detached leaves in the shales and sandstones, incontestibly prove the general analogy and the vegetable origin of coal.*

These views have now obtained the sanction of all competent observers; but there is still a reserve made with many, as to the origin of one species of Coal which is at present brought more prominently before the public, from its recent successful application to the navigation of steam vessels. I refer to the Stone Coal, or Culm of South Wales, the Anthracite of mineralogists, which in its pure state does not occur in the Lancashire Coalfield, though some varieties may occasionally be found. It has been rashly contended that it has not a vegetable basis, because no such remains have been found among it. This is by no means the case, for portions of charcoal occur in the Anthracite of Pensylvania, with its ligneous structure as well preserved as in recently prepared charcoal, (See Silliman's American Journal, 1833,) and the circumstance of Anthracite being found in great quantities in the Great South Wales Coalfield, associated with the well known shales and sandstones, and consisting of almost pure carbon, leave no reasonable doubt upon the subject. In Pembrokeshire the culm measures are distinctly seen reposing upon the Mill-

* Since this paper was read, Professor Johnston of Durham, in a "Report on Chemical Geology" to the Glasgow Meeting of the British Association, has proved the vegetable origin of every kind of Coal, including Anthracite, by a beautiful series of direct chemical analyses, which shew them all to consist of Carbon, Hydrogen, and Oxygen, (the components of living vegetables) differing only in the various relative proportions of these elements.

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stone Grit and carboniferous Limestone, occupying the precise geological position that the bituminous Coal does in the eastern part of the same basin, thus demonstrating that both were accumulated at the same period, and from the same material. In fact there is no coalfield in the world where the age of the deposit is more clearly marked by natural sections, and Mr. Murchison says that plants common to other Coalfields occur not only in the shales, but may be detected in the culm itself, Silur. Syst. p. 373.

2nd. The Geological Conditions under which Coal has been Produced.

The great group of strata found in many districts in this country, and known by the general name of the Coal measures, consists of an indefinite number of beds of sandstones, shales, clays, and bituminous schists, repeatedly alternating with each other, generally containing Ironstone, and imbedding in no regular order of succession, thirty, or forty, or even sixty beds or seams of coal, each varying in thickness from a single inch to five or even ten yards. This great formation succeeds and rests upon the Millstone Grit, which in its turn overlies the carboniferous, or Mountain Limestone. In Belgium, the north of France, the southern parts of England, and northwards to the south of Yorkshire, and in Ireland, no Coal is found below the Millstone Grit; but as we advance still farther northwards, we meet with beds interstratified with the latter formation, and even with the Mountain Limestone. The change first takes place a little to the north of Manchester, where at Gauxholme near Todmorden, two beds of coal are observed to lie within the Millstone Grit. But it is not my intention to enter much into the details of a coalfield which is much better known to most of my hearers than to myself, and as no general interest would be thereby excited, or elucidation afforded of the views I am about to explain, I shall satisfy myself with a few leading particulars of the most remarkable coalfields.

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The greatest accumulation of coal in England is in the Wolverhampton and Dudley district, where there is one bed, ten yards in thickness; the neighbourhood of Paisley presents ten beds whose united thickness is one hundred feet; while the great South Wales Coalfield contains, near Pontypool, twenty-three beds, containing altogether about ninety-three feet of solid coal. Professor Phillips says that generally the aggregate thickness of all the beds of coal in a district, is about fifty feet; but this uniformity does not apply to the accompanying shales and grits, which vary very much in this respect.

Various theories have been framed to account for the production of this enormous thickness of deposits, and especially of the seams of Coal. Some have supposed they have been formed and accumulated from Algæ at the bottom of the sea, or from plants drifted from tropical climates; or in lakes and estuaries from plants brought into them from neighbouring lands, first held in suspension and then precipitated to the bottom; while others have had recourse to a series of reciprocating inundations of salt and fresh water, and of elevations and subsidences of the bottom, which sound geology cannot sanction. Mr. De la Beche says, "By general consent, Coal has been considered as resulting from the distribution of a body of vegetable remains upon a previously deposited surface of sand, argillaceous silt or mud, now compressed into shales and sandstones. After the distribution of the vegetables, other sands, silts or mud, were accumulated upon them; and this kind of operation was continued irregularly for a considerable time, during which there was an abundant growth of similar vegetables *at no very distant place*, to be suddenly, at least in part, destroyed and distributed over considerable areas on the more common detritus. Great length of time would be requisite for this accumulation, because the phœnomena observed would lead us to consider the transporting power,

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though variable, to have been generally moderate; moreover a very considerable growth of vegetables requiring time, would be necessary at distinct intervals; for coal-beds now only six or ten feet thick, must, before pressure was exerted upon them, have occupied a much greater depth." Geological Manual, 402. Ed. 3rd. This is a pretty correct statement of the prevailing views as to the mode of formation of beds of Coal at the bottom of lakes and estuaries, but some parts of the supposed process, as it appears to me, could never take place. It is not denied that some plants might be drifted from neighbouring or even distant lands; on the contrary, this was probably the case in many instances, to some extent; indeed it is rendered almost certain from the occurrence of detached leaves and branches of fern and other plants in most of the alternating shales and sandstones. Such drifted materials would be arrested by shoals, and lodged in hollows or estuaries, or entangled among the mud during its precipitation and consolidation. But there is difficulty in conceiving how the vast masses of vegetable matter necessary to form a thick seam of Coal, being so much lighter than water, could be made to sink and be kept down at the bottom, while a sediment, heavier than themselves, was in the act of being deposited upon them, instead of sinking through and underneath them, as is natural to expect it would do. This difficulty is increased, when we reflect that without a superincumbent layer of mud or sand to give the requisite confinement and pressure, the process of conversion into coal could not go on; for the bituminous matter, and especially the hydrogen, would, from their less specific gravity immediately rise to the surface as they were formed, and be dissipated, and consequently ordinary coal could not be formed. Besides, this supposed distribution of a body of vegetable matter upon a previously deposited surface of sand or mud, could not have been made so uniformly over such

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extensive areas as the beds of coal cover, if it had been drifted by currents; for the natural operation of such currents would be to accumulate it irregularly on either side, while the actual courses of the currents would by their erosive action, be destitute of any portion. In general, the coal-beds, with some modifications, may be traced over very considerable areas; the Lower Main Seam of the Great Northern Coalfield is known to extend over an area of at least two hundred square miles, and is probably continued over double or treble that space; and in our Lancashire series, Mr. E. W. Binney informs me there is a thin coal seldom exceeding a foot, or being less than eight inches, and lying below the Gannister or Rabbit Coal, which extends all the way from Whaley Bridge to Blackburn.

There is no trace of currents or violent action of water in the coal formation. The fine silts and mud, now converted into shales, bind, clunch, &c., are evidences of the most tranquil state of the water from which they were precipitated, and such a thing as a rolled pebble imbedded in these strata or in the coal itself, is rarely seen. These facts seem to indicate that the beds were actually deposited in gulfs or inland seas, where the tides and currents of the ocean were either entirely absent, or exerted but a feeble action. The existing situation of the Gulf of Mexico, into which large rivers pour their tributary waters, offers so many coincidences to what may be supposed took place during the carboniferous period, that a slight reference thereto may help us to form a tolerable idea how the shales and sandstones of the coal formation were deposited, and from whence the materials were derived. Here is an immense area of water extending over eighteen degrees of latitude, and thirteen degrees of longitude, receiving the contributions of numerous great rivers, especially from the north and west; these rivers traverse countries situated in widely different latitudes and climates, and composed of various geological

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formations. One of these rivers, the Mississippi, will serve to illustrate our present subject; and without going much into detail, we may say that it is four thousand miles long, and is the drainage of an immense region stretching from the Alleghanys on the east, to the Rocky Mountains on the west, and eleven times the area of Great Britain and Ireland. Its tributaries are mighty rivers, and the delta formed at its mouth by the sedimentary mud which its waters bring down, is two hundred miles long, and one hundred broad, and is composed of distinct strata varying considerably in colour and specific gravity. The great difference in latitude, and the various mountain chains which head these rivers, their greater or less elevations, and consequently the different months in which the sun can act upon the snows and ices on their slopes, and of the plains in the higher parts of their course, will necessarily cause the floods and freshes to take place in different parts of the summer; and the thick yellow mud of the Missouri, the red clay of the Arkansas and Red River, and the blue and black sediment of some of the other tributaries will be separately discharged into the Gulf, without being mixed up together in the great trough of the Mississippi. Thus sections of the delta which have been cut through by the shifting of the channels, show various alternations of red, black, and blue clays, and sands and muds more or less micaceous, of finer or coarser texture, according to the chemical or mechanical conditions of the formation from which they have been severally derived. The analogy is greater between these deposits, and the shales of the carboniferous era, owing to the slight fall of the waters, allowing the finer particles to reach the delta, while the gravel and pebbles would be left behind near the mouths of the tributaries, where they enter the central valley. Nor are these different sedimentary deposits for the most part carried out by the gulfstream, for hydrographers inform us that a current is scarcely

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perceived to the eastward of the Mississippi, the waters there, and even as far south as the reefs of Florida, and to the Bahama Islands, being among the clearest of the sea-waters yet discovered. The bulk, therefore, of the immense volume of sedimentary mud brought down by the Mississippi, and also by the numerous other rivers that discharge themselves into it, must accumulate at the bottom of the gulf. Nor should it be hastily concluded that the analogy will not hold, because we see at present near the great coal basins of England, no extensive surrounding continents at all adequate to justify the inference that they could have supplied that enormous mass of sedimentary shales and sandstones which compose the coal measures. It is the very extent of this accumulation which may help us to a solution of the difficulty. Geological observations everywhere show that the relative position of land and water is constantly undergoing changes; it can be demonstrated that our present continents have been once the bed of the ocean, and that even at the time when the coal strata were in progress of formation, a large portion of the present continent of Europe was under the sea. If then, we find, as we do among the great northern drift, boulders which we cannot refer to any existing mountains, may it not be supposed that the lands and mountains from which the coal shales were derived, may have been since entirely swept away, and their places now occupied by the ocean? The vast length of time necessary for effecting such extensive changes, cannot be considered a valid objection; for the Geologist soon becomes convinced that immense periods have doubtless been required for the completion of all operations effected by the agency of sedimentary deposits.

The above reference to the sedimentary deposits of the Mississippi is more or less applicable to all large rivers, and is only intended to shew how the shales and sandstones of the coal measures may have been accumulated. I shall

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now proceed to consider the geological circumstances which have produced the intermediate beds or seams of Coal.

The permanency and stability of mountain chains and of the land in general, and the fluctuation of the level of the ocean, used to be, and perhaps still is, except among geologists, the prevailing belief; but the concurrent testimony of all accurate observation of past geological phenomena, and a careful investigation of the changes still taking place in the relative levels of land and sea, prove that the converse is the fact, namely, that the general level of the ocean is fixed and permanent, and has never much varied from what it is at present; but that the land on every part of the globe is frequently undergoing changes from a lower to a higher level, or from a higher to a lower. In the former case, the bed of the ocean was first thrown up into mountain chains, which appeared above the surface as rocky islands, and then by a repetition of the elevatory causes, the surrounding parts appeared as plains and valleys, constituting together, a continent. In the latter case, namely, during a period of subsidence, the valleys and plains first became submerged, leaving the mountains as insulated chains, or completely burying them beneath the waves. So many well authenticated instances of these subsidences and elevations are on record in the works of geologists, and have been collected by the industry of Mr. Lyell, and more recently by Mr. Darwin, that it is merely necessary to mention a few of the most striking.

During the earthquake of Cutch in the delta of the Indus, in Bombay, in 1819, a tract of country upwards of thirty miles in length was converted from dry land into sea in the course of a few hours, but so uniformly that the four towers of the Fort of Sindree continued standing, so that the people within who had ascended to the top saved themselves in boats. Immediately after the shock, at the distance of five miles, rose a long elevated mound, where

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previously there had been a low and perfectly level plain. This newly raised country was upwards of fifty miles in length, and its breadth about sixteen miles. In one geological epoch and district, a series of elevations may be taking place by slight and repeated paroxysmal efforts of subterranean gases at escape, as has long been and still is taking place on the west coast of South America, the shores of the Baltic, and many other places; while on the contrary, a subsidence from the settling of the earth's crust, may either simultaneously, or in another epoch, be going on in a different portion of the surface. In 1692 Jamaica was visited by a dreadful earthquake, and many parts of the coast, with houses, &c., were sunk thirty to forty feet beneath the waves. In 1755, the Quay at Lisbon sank at once to the depth of six hundred feet. A celebrated French geologist, Elie de Beaumont, supposes that in the history of the earth there have been long periods of comparative repose, during which the deposition of sedimentary matter has gone on with regular continuity; and that there have also been short periods of paroxysmal violence, during which that continuity was broken. Mr. Darwin has shewn that in the Pacific, an extent of ocean more than one thousand miles in one direction, and several hundreds in another, is scattered over with islands which are now in a course of very gradual subsidence from the action of subterranean causes. While on the South American continent, elevations are taking place over wide areas with a very uniform force, proofs of which appear in terraces of stones and shells in the high valleys of the flanks of the Andes. These changes of level are now so well understood, that it would be a waste of time to enter into farther details; the general fact is completely established.

The changes which seem principally to have been in operation during the formation of the Coal measures, were subsidencies of the land; and I shall consider these sub-

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sidencies as the basis of what has long appeared to me the most satisfactory and consistent explanation of the facts observed as to the superposition of the beds of coal, and their irregularities in distance from each other, in thickness, and in continuity. It seems to be the only theory which has the advantage of being in accordance with the recognized laws of nature now in operation; and requires none of those accommodating alternations of elevations and subsidencies which have been called in aid by some geologists, but which are required to be too numerous and too regular to merit the sanction of the independent observer. The theory I am about to propose is not altogether new; and in a somewhat modified form has been held by many eminent geologists. Jameson long ago considered that the plants from which coal was formed, once stood and grew in the places where they were buried. Brongniart thought it probable that the beds were formed from vegetables, which after their death passed into a kind of peaty deposits of greater or less extent, on which other vegetables still grew, till, as De Luc imagined, they afterwards slipped into the sea, or by other means, became covered by beds of rocks, and there gave rise to the Coal deposits. If, for this awkward mode of entombment in the waters, we substitute a submergence of the land when covered by the vegetable mass, I think we shall not be far from the truth. The authors of the Fossil Flora after adverting to various circumstances, arrive at the conclusion that the beds of Coal chiefly originated in vegetable matter which lived, died, and was decomposed upon the spots where we now find it; each bed having been the product of an extended surface of marshy land, covered with a rank luxuriant vegetation. (Pref. to F. F., vol. 2, p. xxii.) These views have been recently advocated in a Paper, read by Mr. T. B. Beaumont before the London Geological Society, and are in unison with my own. My opinion is simply this—That

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the trees and vegetables from which the beds of Coal are derived, grew on the identical spots the latter now occupy, when each bed was successively the surface, and probably was but little raised above the level of the waters, either as detached islands or extensive plains or savannahs; that these surfaces, during the settling of the earth's crust, were one after another submerged and covered with sediments from turbid waters, or with drifted clay, sand, and shells which buried up the plants; that these sedimentary deposits *gradually* accumulated till they formed a new surface, which in time produced another growth of plants and trees, and after a second period of rest, were in their turn submerged and covered up by other deposits; and that similar intervals of repose with intermittent occasional subsidencies, were repeated during the entire period of the Coal formation. As each vegetable surface sunk beneath the waters, it gradually became converted into Coal by processes already explained, and the successive deposits of mud and sand became consolidated into shales and sandstones.

The enormous aggregate depth of the whole coal formation, and the great thickness of some of the beds of shale, &c., incontestibly prove the long periods that must have been required to complete them. This slow deposition is in harmony with what we observe in all other geological epochs, and has kept going on till the accumulated sediment has formed a shoal, which has gradually reached the surface, by degrees has resisted the encroachment of the waters, and then established itself as an island. As the channels between different islands became choked up with sediment, marshy plains or morasses would be formed, and would unite the islands into plains, upon which vegetation would soon commence, and favoured by great heat and moisture, would rapidly prepare a soil for the growth of the larger succulent plants, and for forests of hardwood trees and coniferæ. All this, however, implies a long interval of

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rest; for however rapidly the lofty soft and spongy Lepidodendrons and creeping Stigmarias would develope themselves in a moist atmosphere and uniformly high temperature, many generations of them must have been necessary to supply a sufficient quantity of vegetable mould for the forest trees, and of carbonaceous matter for the thicker beds of Coal, reduced as they are in bulk, by subsequent superincumbent pressure. The Fossil Trees which were lately discovered in our own neighbourhood, on the line of the Bolton Railway, and which will form the subject of a separate paper, throw out roots as thick as those of an oak two hundred years old, and must have required a long period for their growth. Centuries of rest have probably elapsed during the accumulation of those vegetable masses in which the thicker seams of Coal have originated; while the extreme thinness of others, proves that the paroxysms have taken place at irregular intervals, and have sometimes succeeded each other rapidly.

The annexed series of ideal sections (Plate II. No. 1, 2, and 3,) has been constructed to assist the reader to understand this process. The whole are supposed to represent the same portion of a Coal Field at different periods of time, and in different stages of submersion. In all, the horizontal line AA represents the permanent sea level, and the respective letters point out the corresponding beds, whether of Coal, Shale, or Sandstone, which may be all identified in the same relative position through the series. The surfaces of vegetable matter are shewn by perpendicular lines; and where submerged and converted into Coal, are crossed by horizontal lines. No. 1 represents the earliest stage of the series (though long after the commencement of the carboniferous era) just after partial subsidences of the surface at *a* and *d*, which are covered with water, and while vegetation is still flourishing on the intermediate undisturbed portion. In No. 2, the level of the land remains the same,

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but a long period having elapsed, the water at *a* and *d* has been displaced by accumulations of sediment, which have formed a new surface, and been covered by fresh vegetable matter; while in the mean time vegetation has been proceeding on the unsubmerged portions, and accumulating a thicker mass than is contained in both the beds *b* and *c*, with which it unites, the lower bed, *b*, being partially or altogether converted into Coal. No. 3 shews the same deposits at a still later period, after the whole has undergone another and more general subsidence, the vegetable surfaces, *b* and *c*, being covered up by fresh sediments, and converted into Coal, and the whole buried beneath the waters. These sections will illustrate many existing appearances; first, the formation of a thick and often irregular seam of Coal by the union of two or more thinner ones; second, the interpolation of a stratum of shale between two beds of Coal, where the shale gradually thins out and is replaced by Coal (*d* in No. 2 and 3); and third, the process by which fossil trunks have been imbedded and filled with inorganic matter. This will be explained more at large in the Paper on the Fossil Trees, found on the line of the Bolton Railway. The deposit of sandstone which surrounds the top of the imbedded trunk in Sections No. 2 and 3, is introduced to shew how the latter comes to be filled with a different material to that which surrounds it; the same bed is not continued at *d*, beyond the central portion, because the subsidence on that side, being less, and the depression shallower, it has been filled up to the surface with the previous deposit of shale, *d*, before the water became mixed with sandy sediment. This will explain why a particular bed of shale, &c., which is found in one situation, is often deficient at a very short distance, even where no fault intervenes.

There is a peculiarity in the texture of Coal, which has not received the attention it deserves. If it be closely

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examined, it will be found to consist of a series of parallel horizontal laminæ, varying in thickness from the fourth to the sixteenth of an inch, often adhering closely together, but sometimes with an intermediate layer of fibrous glossy charcoal, in broken portions, which causes it to separate easily. These laminæ are best observed in the cross fracture, and often exhibit considerable difference in compactness and lustre, some being so much more bituminous and shining than others, that they may be traced for a great length. This structure, though in some coal seams indistinct, is so general, that it seems to point to some law which the chemical geologist might advantageously investigate. Does the Coal of some of these laminæ differ in the proportions of its carbon, hydrogen, and oxygen, from others above or below it? Has that which contains more hydrogen, because formed from resinous vegetables, (the coniferæ), separated and arranged itself above others while in the fluid state, because its specific gravity was less? Does this laminar structure indicate that each thin layer, as it became bituminized, has been separately converted into Coal by a process commencing at the bottom of the mass, and proceeding gradually upwards? Or, lastly, can it be reconciled with the idea of the simultaneous consolidation of the whole bed?

There is another feature in every Coal Field, familiar to all connected with the working of the mines; I allude to the inequality in the thickness of some of the seams. This may be accounted for by the irregularity of the subsidence over extended areas, and may result from the greater or less distance of different parts of the vegetable surface from the axis of convulsion. The disturbances would act with various intensity upon a plain or morass, extending over fifty or one hundred square miles, elevating some portions, perhaps, and depressing others below the level of the waters. We will suppose such a movement as this to take place after a

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long period of rest, during which a thick stratum of vegetable matter had been accumulating, which had hitherto preserved a pretty uniform thickness. What will be the result? The progress of vegetation immediately ceases upon those portions which have been submerged, and they are soon covered with a deposition of mud, sand, or silt, which, if no second submersion take place, will continue to accumulate till it reaches the surface of the water. Vegetation will then commence upon it, and will go on simultaneously with that on the contiguous land, where, during this interval, not having been submersed, it has been going on uninteruptedly, and increasing the thickness of the bed. (See No. 2.) At length another and more general subsidence takes place; the whole area of the plain is sunk beneath the waters, is gradually buried under a series of muddy sediments, and by time and pressure is ultimately converted into Coal. When again exposed, a vertical section would present the appearance shewn in No. 3.

It will easily be comprehended how these partial subsidences might be modified by local circumstances, so as to produce that variety in the thickness of the beds, which is often found in different parts of the same Coal Field; as well as to account for the occasional thinning out of the coal seams,* and for the interposition of shale, clay, or sandstone in thin beds, or in scattered patches within the Coal. (See No. 2 and 3.) A bed of Coal formed from the vegetation of an insulated tract, would necessarily be limited to a corresponding shape and extent; but other neighbouring lands would also be covered with vegetation; and it is easy to understand that a seam of Coal formed from the whole by a general subsidence, would be distinguished by some discrepancies and interruptions of continuity. We may thus

* In Shropshire these are known by the name of Symon Faults. See an illustrative diagram in Murchison's Silur. Syst., p. 102.

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account for those partial irregularities which occur, amidst a general uniformity in all extensive Coal Fields.

The subsidences of which I have been speaking, must not be confounded with those more violent convulsions which took place after the consolidation of the beds, and subsequently to the carboniferous era; which broke up whole districts in every direction, elevating some portions, and depressing others, and produced those extensive dislocations generally known by the name of Faults.

In the following paper on the Fossil Trees, found on the Bolton Railway, I have ventured to draw some conclusions relative to the time that has probably been required to produce a given thickness of Coal, and the amount of shrinkage it has undergone in passing into the solid state. These might have been appropriately introduced here; but as they are so closely connected with, and founded upon, the characters of the trees described in that paper, I shall content myself with simply referring the reader to them in a subsequent part of the present volume.

In conclusion, I have not adverted to the question that has been often asked, whether the water that prevailed at the period of the coal formation were salt or fresh, because it does not affect the views I have endeavoured to explain, as to the formation of Coal. It is probable that both salt and fresh water were present at different periods, and in different portions of the field; for while the corals and shells of the intermediate Limestones in the Newcastle district, and the Pectens and Goniatites of the lower measures in Lancashire and Yorkshire, indicate marine conditions, the Unios and Cypris of the upper measures are equally strong in favour of a fresh water origin.

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ART. VI.

Observations on the Characters of the Fossil Trees lately discovered on the line of the Bolton Railway, near Manchester. By J. E. BOWMAN, F.G.S. & F.L.S.

Read 30th January, 1841.*

As the Fossil Trees, whose nature and history I have undertaken to investigate, have already been the subject of some able observations by Mr. Hawkshaw, to whom geologists are indebted for their discovery and preservation, I shall merely say that they were discovered in the spring of 1839, on the line of the Manchester and Bolton Railway, near the Dixonfold station, and about 5½ miles N. W. from Manchester. They all stand in nearly an erect position, their inclination being about fifteen degrees from the perpendicular S. by W., corresponding with that of the strata, and showing that before the displacement of the latter, they must have stood erect. The material on which they stand is a thin bed of pure bright coal, eight or nine inches in thickness, which divides into long slender parallelograms; on this the large roots spread out in all directions, slanting downwards from the trunks, and resting upon, but not penetrating into the Coal, which underneath them is more splintery and impregnated with sulphuric acid than in other parts. All except No. 1 are below the level of the railway, and are inclosed in round walled pits, so that the roots cannot be traced beyond a few feet, and the trunks are

* Read also before the Geological Society of London, 26th Feb., 1841.

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unfavourably situated for being seen or sketched. They lie in a stratum of soft grey argillaceous shale, about four feet thick, among which great quantities of nodules, containing cones of Lepidostrobus, with pieces of Stigmaria, &c., were found. Upon the shale is a bed of fine grained sandstone, about four feet thick, but the change from the shale is very gradual, and no definite boundary can be seen. Of this sandstone the trunks of the trees for the most part consist.

The diameter of the largest, No. 1., at the base is 5ft., and a little above it 3ft. 3in., at 3ft. high it is 2ft. 6in., and at the top 2ft. Its present height is 8ft. 9in., when Mr. Hawkshaw measured it, it was 11ft.; and workmen who were present when it was first laid bare, say that it was then still higher. No part of the roots can be seen; the swollen base indicating their commencement, is of hard sandstone, mixed with much carbonaceous matter. At 2ft. above the base there is a remarkable horizontal band of blue shale, containing many thin plates of sandstone and streaks of charcoal, about 10in. thick, which, from its more rapid decay, gives the trunk the appearance of being contracted in that part. This shale band is a very important feature, and will be again referred to. The carbonaceous exterior was for the most part crumbled off; the little that remained was not more than ¼th to ⅓d of an inch thick; traced with faint and fine longitudinal lines, but no scars like those on *Sigillaria* were observed. The greater part of the trunk was therefore decorticated, and in most places was marked with rude irregular ribs from ½ to 1½ inch wide, slightly convex, and parted by shallow and narrow irregular furrows, by no means so parallel, and equally bifurcated as in the stem figured by Brongniart from the mines of Anzin. (Hist. des Veget. fossiles, vol. 1. pl. 160, fig. 3.) Some of the ribs divide; others unite without order, and are made up of detached portions, having a wavy diagonal direction, and towards the base become more indistinct, intermix, and

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finally disappear; and their general surface is faintly streaked with intercepted patches of irregular lines. As it was impossible to convey a definite idea of these by description, I placed paper on the most perfect parts, and by pressing it into the furrows, I have preserved exact impressions, which are deposited in the Museum of the Manchester Geological Society.

The only trace of scars I could find after a long and close search, was in one place near the base, and though faint and irregular, they were still sufficiently defined for an eye practised in the coal fossils, to be recognised as those of *Sigillaria*. The fine wavy lines so often found on decorticated specimens of that family, might be seen in many places on the ribs. As the front and sides only of this fossil are exposed, I found that the undisturbed matrix behind was not in contact with it, but that there was an interval varying from an inch to an inch and a half, which was filled up with a fine light coloured shale, much stained in places with ferruginous matter, and marked on the surface with longitudinal ribs, though less distinctly than the decorticated parts. On removing this intermediate layer, I found it to be made up of a single series of longitudinal columns, whose flattened sides were very closely pressed against each other, but prevented from actual contact by a thin partition of pure coal, not thicker than a wafer. Both the coal and contiguous lateral surfaces of the columns were traced longitudinally with fine parallel striæ, convex on the latter, grooved on the former, and being exact counterparts of each other. These intervening plates of coal have their edges directed inwards and outwards, and their flat surfaces at right angles with that of the trunk, divergent from the axis, like the medullary rays of modern timber trees. They are connected together underneath, or on the decorticated surface of the trunk, by a similar continuous, though thicker layer of Coal, which forms the coat or bark of these fossils when they are

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first exposed. It would thus appear that the original bark was longitudinally grooved, and had a series of intervening elevations or processes, which having become carbonized, divided the surrounding shale into the rib like portions already described. I was so struck with this singular arrangement, that it was not till after several examinations in different parts, that I became fully satisfied of the fact; and I have in this, and several other instances, gone into details, at the risk of being tedious, that no part of the evidence as to their structure, which these fossils have supplied, might be left unrecorded. The interior continuous layer of coal was not above the eighth of an inch thick; and it is not easy to understand how so large a tree should have so thin a rind, compared with that which is often seen on much smaller specimens of Sigillaria reniformis, to which I refer the tree I have been describing. There was no trace of the longitudinal ribs, either on the surface of the argillaceous exterior of the tree, or on the cast on the face of the matrix in contact with it; but on both a rough coat of scaly ferruginous matter.

No. 2, (See Plate 3) is but the stool or base of a trunk 8ft. 2in. in girth, and nearly 2ft. 6in. in diameter. The ribs and furrows on the surface are similar to those on No. 1; and are seen in places on the sides of a deep wedge-shaped rift on the S. E. side, which has been coated with coal, and is strongly marked with wavy raised lines running without any order in various directions, very like the surface of the alburnum of a gnarled oak after the removal of the bark.* But the most important features are the enormous roots, which strike off in different directions, slanting downwards at an angle of twenty-nine degrees with

* This appearance is well shewn in a portion of the trunk preserved in the Museum of the Manchester Geological Society; where are also several specimens of its furrowed roots.

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the horizon towards the coal, but are abruptly cut off when they reach its surface, which is covered with about an inch of whitish unctious clay, nor could any trace of roots be discovered within the coal when searched for. The three principal roots that remain (one being destroyed in excavating,) have each a diamater of 20in. to 2ft.,* and their surface is marked with ribs and furrows which diverge on each side of lines which are parallel with the longitudinal axis of the root; a character which, as far as I am aware, no modern roots possess.†

No. 3 is smaller, its height being only 2ft. 3in., girth at the base, 5ft. 10in., girth at top, 4ft. 1in., its diameter at top, 1ft. 2in. Its surface is much smoother, having a few irregular and broken furrows, but is covered all over with faint rather slanting lines, which on different sides, diverge in different directions, and are apparently natural, and not the effect of outward pressure. They were too faint for me to succeed in taking an impression. There is a remarkable longitudinal concavity or depression on the S. side, 4in. wide, which is deepest at the base (4½in.) and gradually narrows upwards, till it disappears near the top.

No. 4 is about the same size, (height 2ft., girth at base 5ft. 5in., ditto at top, 3ft. 6in., diameter at top, 1ft.) It is remarkable for its swollen base, and has a broad shallow longitudinal depression. The ribs are narrower, but much more prominent, wavy, and rugged, than any of the other specimens, often bifurcating or running into each other, and are traced with fine longitudinal lines, like those of growth.

* That towards the E. is 2ft., and that to the W. 2ft. 2in. in diameter.

† The arch between the great roots underneath the trunk offering an opportunity, I excavated the clay and shale to ascertain if any tap root descended perpendicularly downwards, like that of an untransplanted oak, but there was no indication of any. Unfortunately this tree is in a state of greater decay than the rest of the specimens, owing to the admixture of shale with the sandstone. It is already cracked and broken in all directions, and its complete destruction at no distant period, is inevitable.

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No. 5, (See Plate 4) is a larger specimen, 5ft. 3in. from the base to the top, where its diamater is 2ft. 4in., and its girth 7ft. 8in., girth at base, 10ft. 4in. It is ribbed and furrowed like No. 1 and 2, but in one place the ribs seem to have been forced out of their natural direction. There are no scars, but the ribs both in the corticated and decorticated parts, are more distinctly marked with longitudinal wavy striæ. The coaly exterior near the base is in two plates, one crystallized parallel to the surface, the other at right angles to it. The ribs may be traced down to the roots, though they become very irregular, and constantly run into one another like the crossing rifts in the bark of an old Spanish chesnut. The main root before it bifurcates, has the extraordinary diameter of 4ft. 6in., but it may probably have been flattened by pressure. The most striking feature of this specimen is a concave depression along its whole length on the N. side, and it has evidently extended much higher. It is 12in. wide, and 3in. deep, ribbed and furrowed, though faintly, and is covered with a thin coat of coal which is striated. A similar depression has been mentioned on No. 3, and as they are too constant and regular in their characters to be accidental, I could not help suspecting they might be the places where some cylindrical column had been pressed against the tree while in a growing state, such as a parasitic plant, like the ivy, or the cable-like lianas and climbers of tropical forests. There is, however, another smaller depression on the W. side, partially filled with the surrounding shale, but shewing no trace of any other substance having been in contact, at least at the time it was imbedded; so that I must leave this point as I find it.

No. 6, the latest discovered tree, is situated on the N. or opposite side of the railway, and twenty-four yards nearer to the Manchester terminus. It is about 2ft. high, and 1ft. in diameter at the top, and at least double that amount at

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the base, where it resembles a large bulb. The surface is obscurely ribbed, smooth and streaked like No. 3, and where the coaly shell remains, it is half an inch thick. In one place it shews precisely the long prominent scars of a decorticated Lepidodendron. It differs from all the rest in having an irregular longitudinal cleft through its centre at the top, the inner walls of which shew a striated surface, and are coated with coal. Is this the base of a bifurcation? or has there been a rift which has been in process of reparation by a deposit of new wood?

Such, very briefly, are the appearances which an attentive examination of these extraordinary fossils presents, and I think that no one who is at all aware of the conditions of the globe when they were growing upon its surface, and of the vast interval that has since elapsed, can view them, converted into solid rock, without deep and strong emotions, nor without a conviction that they are still standing on the spots where they originally flourished. Nor would it ever be suspected that they were of that soft succulent nature which many of the gigantic vegetables of the carboniferous era undoubtedly possessed. On the contrary, their general character, size, and robust habit, are precisely those of any aged and decayed tree of the present day; the trunks much widening below, where the enormous roots strike off, and appearing as the remnants of a forest of blasted and lifeless oaks, whose boles and roots alone survive. Their enormous roots were manifestly adapted for taking firm hold of the soil; and in conjunction with the swollen base of the trunks, to support a solid hardwooded tree of large dimensions and spreading top, in an erect position, and to enable it to resist violent storms. It is true we have here no direct evidence of a branched trunk and spreading foliage; but such have been found in the coal districts of England, fossilized and branched in the same way as our forest timber.

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With reference, therefore, to Fossil Trees in general, and especially to those at Dixonfold, I shall now endeavour to show,

1st. That they were solid, hardwooded, or timber trees, in opposition to the common opinion that they were soft or hollow.

2nd. That they originally grew and died on the identical spots where they are now found interred, and have not been drifted from distant lands; and,

3rdly. That they have become hollow from the decay of their wood by natural causes still in operation in tropical climates, and have been subsequently filled with foreign inorganic matter, precipitated as a sediment from water.

1st. That they were solid timber trees. It is well known that modern trees in temperate latitudes, increase in thickness by means of a new layer of wood formed annually between the bark and the alburnum. The more or less perpendicular rifts or furrows in the bark of full grown trees, are owing to the expansion caused by these new deposits, and so is the thickening or swelling of the base of the trunk and main roots, and the *apparent* tendency of the main roots to rise above the surface of the soil, which is always most observable in the oldest trees, and never in young ones, and is owing to the chief increase being on the *upper* surface, or the side most influenced by light and heat, for the same reason as the rings of the trunk are thickest on the south or sunny side. Of a similar character are the swollen base and far extending roots of No. 2, which diverge downwards from the stool, at an angle of twenty-nine degrees with the horizon. But no soft monocotyledonous tree, such as Palms and arborescent ferns, to which these fossils have generally been referred, have this economy, their stems not swelling laterally by new layers one over another, but growing *upwards* only, and from *within*, and being as thick when they are only a few years old, and a foot

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high, as when they attain the age and height of sixty or one hundred. Nor have such plants the massive forked roots of ordinary forest trees, but generally a dense assemblage of straight succulent fibres, like those under the bulb of an onion or a hyacinth. Analogy, therefore, as far as outward shape and habit are concerned, is strongly in favour of the fossils having been solid timber trees.*

Geologists have generally considered all fossil stems with perpendicular ribs and furrows, such as Sigillaria, to have been succulent or hollow, because they are always found filled with shale or sandstone, which has evidently been subsequently introduced in a soft state, because it often contains the leaves, &c., of other fossil vegetables. But the fine, straight, curled, or gnarled striæ to which I have alluded, and which may be traced upon the decorticated parts of good specimens of Sigillaria, are so similar to those on the alburnum of many modern forest trees, as to render it probable, and in conjunction with other evidences, almost certain that the fossils had, like them, a separable bark, a character which in vegetable physiology is considered to be the proof of a woody structure. It may also be remarked, that the little prominences on the surface of the alburnum seen in barked timber, which arise from the formation of new wood over the yet concealed buds in their progress outwards, have their representatives in many of the decorticated parts of these fossil trees. The scars also left by the disarticulation of the leaves, are indicative of a dicotyledo-

* I know not why there should be so much difficulty in admitting this to have been the case; for it is evident from the abundance of soft and silky layers of charcoal, still showing its fibrous woody structure, which forms the surface of most beds of coal, and subdivides them into laminæ, that timber trees must have been common during the carboniferous period. This evidence exists on the coal on which these trees stand; I found it even within the space which the extremity of the root of No. 2 covered, when endeavouring to trace it down into the coal, and it would be difficult to prove that it is not the remains of the wood of this identical tree.

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nous, if not of a wooded structure. I could only find these scars in one spot on No. 1, and I attribute their rare occurrence on large and old trunks of Sigillaria, to obliteration by irregular expansion from the subsequent deposition of new layers of wood.* This process, annually and unequally repeated for a long period, will also most satisfactorily account for that indistinct and irregular arrangement of the ribs and furrows, their want of continuity and parallelism, their divisions and inosculations, which are so striking on some of the Dixonfold trees, but which are never seen on small specimens of Sigillaria.

In addition to the evidences I have given of the woody structure of the trees before us, I am able to add another still more decisive, in a specimen found by myself and Mr. Binney on the bank of a cannel pit, three or four hundred yards towards the N. W. of the Dixonfold trees. It formed a portion of a fossil tree which had been cut through in sinking down to the Cannel, whose geological position is below that of the thin coal which bears the trees under discussion, of which it probably formed one of the same group. The great mass of this tree was filled with shale containing leaves of ferns and other fossils, but on one side, within the carbonized bark, was a patch that was browner, harder, and more compact than the rest, and which appeared to have preserved its original structure. This was fully ascertained by thin polished slices obtained by the method adopted by Nichol and Witham. My friend, Mr. Robert

* I have named scars on No. 6 as precisely those of a decorticated Lepidodendron, and as the root of this specimen is much swollen, it might be argued that as those fossils have been shewn to have had soft succulent stems, the other trees with roots probably had such also. But this would not be correct, because, first, the swollen base of No. 6 is of a very different character from the gradual thickening of those of No. 1, 2, and 5; and secondly, there is no difficulty in admitting that a soft monocotyledon might grow among hardwooded timber trees, as at present in tropical forests.

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Brown, kindly undertook to direct longitudinal, transverse, and oblique sections to be taken, that the structure might be examined in every direction. That profound botanist, after a close examination of the sections, has favoured me with the result, and has kindly permitted me to state it on his authority; so that I need say no more as to the accuracy of the observations, or to the value and importance of the evidence they establish.

In the transverse section there is that uniformity of vascularity which is evidence of the coniferous structure. The longitudinal section taken perpendicular to the medullary rays, does not satisfactorily confirm this evidence, inasmuch as very little structure remains, and that little exhibits the tubes *obliquely* cut. In the longitudinal section parallel to the medullary rays, the existence of these rays was ascertained; so that we arrive at the following highly important results. In the transverse section, the uniformity in size of the cells, shews an affinity to coniferæ, and their arrangement in parallel rows or lines is indicative of intermediate medullary rays; while in the longitudinal section parallel to them, they (the rays) have been proved to exist. The specimen therefore exhibits proof of dicotyledonous structure, and considerable probability of that structure being coniferous. But the more important evidence derivable from the presence of discs in the sections made parallel to the rays, is wanting, the vessels having apparently undergone some alteration. This specimen therefore, independent of the question whether its exterior markings correspond with those of Sigillaria, and whether or not it formed one of the same group with the Dixonfold fossils, establishes the important fact, that *some at least* of those trees which are believed to have been originally hollow because we find them filled with inorganic shale, were in reality solid timber trees of dicotyledonous structure.

Other inferences might be adduced in favour of the wood-

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ed structure of these trees,* but as they are connected with the remaining divisions of the argument, I will proceed,

2ndly. To shew that they must have originally grown and died on the identical spots where we now find them interred, and have not been drifted from distant lands.

Having attributed the formation of the beds of coal to a series of subsidencies of the surfaces on which the vegetables which produced it, grew, it seems naturally to follow that the trees also flourished on the same spots. The advocates for the Drift theory account for the upright position in which trees are often found, by supposing that they readily assumed that position from the greater specific gravity of their base, and the soil entangled among the roots. This is correct as long as they continued to float in deep water and a moderate current; but when they grounded on shoals, or were cast ashore, they would generally fall and lie prostrate. Mr. Hawkshaw has very judiciously observed that it is much more difficult to conceive how a number of great trunks should have been left standing, side by side, in an uniform and nearly upright position, and in precisely the same angle with, and perpendicular to the plane of the surface, by the accidents and varying eddies of a current, than that they had grown in the places where we now find them. We must not forget that the material which envelopes the roots and lower parts of the trunks to the height of five or six feet is a fine

* I have great satisfaction in being enabled to state that some recent investigations of Mons. Adolphe Brongniart go very far to confirm the views here advanced. In a letter to myself, dated 21st March, 1841, he says, "What you tell me respecting your fossil trunks of Sigillaria is deeply interesting, and very well agrees with what I have myself observed in a small specimen of *Sigillaria elegans*, the internal structure of which has been preserved. I have just described it in a Memoir inserted in the 1st vol. of 'Archives du Museum d' Hist. Nat. de Paris,' in which I have endeavoured to prove that it has the nearest affinity in its internal structure to the Cycadeæ, which have essentially the organization of Dicotyledons."

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smooth blue shale, which is soft and unctious at the bottom, and could therefore only have been deposited from tranquil water. These great trunks could not have been floated and stranded where we find them, without the aid of a considerable current; and under such circumstances the fine particles of mud of which the shale is composed, must have been carried away. This muddy deposit round their base is therefore a strong proof of the absence of any current. The trunks of modern trees generally stand perpendicular to the horizon, even when they grow on mountain slopes, and the fossils being found in this position as regards the plane of the surface, is strong presumptive proof of their being still in their native situation. If this be admitted, it also proves their fabric to have been strong, and their roots firmly fixed, or they would probably have been tilted aside by the subsidence of the bed. Besides, it generally happens that *upright trunks* are found either upon, or a little above, a bed of coal; whereas, had they been drifted, the chances are in favour of their having been more frequently thrown upon the alternating shales and sandstones, since these compose a much larger proportion of the entire mass of strata. Drifted materials, being at the mercy of various modifying and accidental causes, can never exhibit uniform results. The theory of subsidences, on the contrary, corresponds with observed facts. If the coal seams are the accumulated remains of many generations of a luxuriant vegetation, this rich compost would be the most likely situation for the growth of trees, as it is at present in tropical forests. Nor is it any objection that the roots seem to be cut off when they come in contact with the coal, for the fermentative process would probably destroy the vegetable texture of all below its surface. The parts that rise above the coal, shew they were composed of hard ligneous fibre, from around which the soft half-formed coal has subsided, just as in some bogs in Ireland, as Mr. Murchison informs us (Silur.

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Syst. p. 559) the bases of the trunks of ancient forest trees may be seen still standing in their natural position, "as if on high stilts," with their roots exposed, owing to the shrinking of the surrounding peat. And if it be thought that the weight of the solid trunks would have caused them to sink into the fluid bituminous mass, I reply that being then immersed in water, the consequent diminution of their specific gravity would rather have tended to float them, had they not been kept down by the pressure of the surrounding muddy sediment upon their roots and trunks.*

Having shown the great probability that these trees still occupy their original sites, I have now to show,

3rdly. That they have become hollow from the decay of their wood, and have been subsequently filled up with sedimentary deposit after immersion.

Mr. Hawkshaw has stated in a Paper read before the Geological Society of London, that in the virgin forests of the torrid zone, the solid wood of fallen timber trees rapidly decays, while the surrounding bark retains its texture and original appearance. Perhaps the wood is acted on by a kind of fermentation superinduced by a stagnant, hot, and humid atmosphere, aided by the attacks of xylophagous insects, while the bark may be preserved by some antiseptic or chemical properties. Be this as it may, the fact is established. Mr. Hawkshaw's connection with the mines in Venezuela gave him many opportunities for ascertaining the length of time necessary to effect the decomposition of the

* My friend Professor Phillips of York, though favourable to the Drift system, at once acknowledged to myself and a geological party, while viewing these trees, his conviction that they must have grown upon the spot; and he added, with his characteristic candour, that the sight of them had relieved his mind from doubts and difficulties that had for years perplexed him. Shortly after this, I had the pleasure to accompany Professor Agassiz to inspect them; and he did not hesitate to express his conviction, from the evidence of the roots alone, that they had been solid timber trees, and had grown upon the spot.

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wood under such circumstances. In clearing out roads from the coast to the mines through the dense forests of the interior, numbers of timber trees were left, because not wanted, by the sides of the avenues; and he was surprised to find that in the short space of six, nine, or twelve months, the wood of many of them *had not only decayed, but had altogether disappeared*, leaving the bark sound and unaltered; so that the trunks, though to the eye they seemed perfectly sound, became hollow cylinders, and if struck or trodden on, readily gave way and collapsed. In this manner the rude bridges thrown across the streams, deceived the inexperienced and unsuspecting traveller, and precipitated him into the water. Mr. Hawkshaw informs me he was surprised to find that the hard fibrous exterior, and even the soft central parts of palms and tree ferns, resisted decay much longer than the hardwooded trees.

Mr. Schomburgk, the botanical traveller, and the discoverer of the splendid *Victoria regia*, fully corroborates Mr. Hawkshaw's observations as to the decay of the wood while the bark remains sound; and informs me that one of these hollow deceptive trees gave rise to an incident named in an unpublished part of his journal. He repeatedly observed the fact during four years' travels in Surinam, particularly in the low and hot districts; and he has permitted me to state it on his authority.* We have, therefore, the testimony of scientific and botanical travellers, that at the pre-

* Since this Paper was read I have had a letter from my friend Gardner, who has added so much to our knowledge of the botanical riches of Brazil, dated Rio Janeiro, 6th December, 1840. In reply to my enquiries as to this fact, he says, "Nothing is more common than to meet with the trunks of large trees lying on the ground, not only in low swampy forests, but also in the dense virgin forests of mountain tracts (e. g. the Organ mountains) covered with mosses, ferns, and other herbaceous plants, which to the eye appear quite sound, but which in reality consist of but little more than a thick bark, which gives way immediately to the weight of the traveller, should he incautiously step upon it."

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sent day the solid wood of forest trees in hot and humid climates rapidly decays, while their exterior remains sound, and is converted into a hollow cylinder. We can therefore no longer hesitate to believe, with the many evidences we possess of the high temperature of the Coal æra, that a similar process then took place. It must not, however, be lost sight of that the fossil trees were standing more or less upright, and immersed in, though not covered by water.

After the immersion of the trunk, the boughs and top would remain exposed to the heat and humidity of the atmosphere, at the same time that its roots and stem would be excluded from those influences by the surrounding water; and under these unnatural circumstances, the tree would by degrees loose its vital energy and die. Its top and dead branches would be the sport of the elements, and be torn away one after another, while the mud from the turbid waters would be forming a compact sediment round the trunk, sealing up the bark, in which incipient fermentation would soon commence, and go on till it produced bituminization and converted it into coal; for being under pressure and covered by a cement of mud, the hydrogen and other disengaged gases could not escape. The carbonized bark would then be in a condition to resist all farther action of the atmosphere, to which its inner surface would be exposed on the decay of the wood; for it seems scarcely necessary to say, that after the boughs had rotted away, and so long as the top of the trunk remained above the surface of the water, the heartwood would be as much exposed to the atmosphere as if the tree stood on land. Thus its decay would go on till all the wood, including that of the roots, was completely removed; but as that portion of it in contact with the bark would be the last acted on, it is probable that the carbonization of the bark would be first completed. At all events the carbonization seems never to have extended to the wood *inwards*, nor the decay to the bark *outwards;* it being clear from the minute

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and regular wavy lines of growth seen upon good decorticated specimens, that both processes have been arrested precisely at the union of the liber and the alburnum.* I think it therefore probable, that considering the half immersed condition of these trees, they would struggle for some years between life and death, while the carbonization of the bark would be going on outwards, and the decay of the wood inwards; and that they would only submit to a lingering death when all their top was gone, or they became completely immersed by a second subsidence. The carbonization of the bark would probably not take place where it was not surrounded by sediment; and this may explain why boughs and branches are not found in *upright* fossil trees. Every part above the carbonized line would soon perish.

We have then in these upright immersed trunks, so many hollow cylinders or moulds, ready to receive the sediment precipitated from the turbid waters. The process of filling up would commence as soon as the top of the broken trunk decayed below the surface of the water, and the wood was sufficiently removed to admit the deposit. The mud first admitted would be of the same quality as that suspended in the water at the time; if no change took place before the cylinder was filled, all the included column would be of one kind; but if, during the process, the sediment, from being argillaceous became arenaceous, the lower part of the tree would be shale and the upper would be sandstone; as many alternations would appear in its trunk as in the equivalent deposits above, but on a lower level; and the line of sepa-

* Every one acquainted with the laws of vegetable physiology is aware that in modern trees this is the part where the vital energies are most active and longest continued; its effects may be observed in any old tree not quite dead; for if only a small portion of living bark be left on one side, a few branches and foliage will be found above it, though the rest of the trunk be hollow and decayed.

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ration between them would be more or less clearly defined, as the change was gradual, or sudden. It is obvious that if the tree had been originally hollow and of uniform diameter, the sediment admitted would correspond both in quality and thickness with that on the same level around it. If on the contrary it had been solid, no sediment while it continued so could be introduced; but if *in process of time it became hollow by decay*, it would then be in a condition to receive whatever sediment the water might at that time be depositing; it being borne in mind that it was submerged, standing erect or nearly so, with its lower portion buried up by the deposits that had been accumulating round it while solid. In the latter case the strata on the same level within and around the trunk, would not correspond; but the introduced matter would be found to resemble in quality and generally in thickness, the beds above from which it was derived, or of which it was the equivalent, the intervening space being greater in proportion to the length of time the tree had continued solid.

To make this more intelligible, I have introduced a tree in several different stages of this process into Plate 2, which explains the formation of Coal by subsidence. In the ideal Section No. 1, its trunk *e*, appears immersed, while its top is above the surface, and its branches are broken off. In No. 2, though no farther subsidence has taken place, its top is decayed below the surface, but the water has given place, first, to a deposit of shale, *a*, which surrounds the trunk, and next, to another of sandstone, which last has been admitted into the *now* hollowed trunk, and has filled its interior. This sediment having attained the surface, has been covered by a new vegetation, *c*. In No. 3, the whole has been sunk deeper by another more general subsidence, fresh deposits from the water have covered up all the former vegetation, and converted it into Coal, and the trunk, filled with inor-

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ganic sandstone, but retaining the original markings of its exterior, has become in every respect, a Fossil Tree.

I will now briefly describe the actual conditions of the tree No. 1, and of the surrounding strata, and then see how far they can be reconciled with the above theory. I need not repeat what I have already said of its size, or of the clear indications of vegetable structure impressed upon its surface. The trunk of this fossil is a compact fine-grained sandstone, with an intermediate horizontal band of shale, *b* in Section, Plate 5, nine or ten inches thick, the bottom of which is two feet above its present base, and which separates the sandstone into two distinct beds. It is distinguishable from pure argillaceous shale by a mixture of sand, and where weathered, is seen to consist of a number of very thin plates of soft bluish sandstone, with intermediate laminæ of shale. It is separated from the contiguous sandstone, both above and below it, by an abrupt and definite line, indicative of sudden changes in the nature of the deposit, which changes are the more remarkable, because in the Coal measures, the transition from one kind of deposit to another is generally so gradual and indefinite, that it is difficult to fix the boundary line. The matrix that envelopes the lower half of the tree, and lies upon the nine inch seam of Coal, *c*, Section, Plate 5, is a blue or grey argillaceous shale, that imperceptibly changes upwards into a sandstone, not distinguishable from that which forms the tree itself. On a cursory view, this sandstone appears to be of considerable thickness on the slope above, but owing to the fall of detritus, and the effects of weathering, the face of the beds is so much obscured, that it is difficult to trace them; but on laying them bare, a *well defined* bed of laminated shale, *a*, Section, Plate 5, may be seen inserted between the thick sandstone. This sandstone gradually changes upwards into another bed of shale, which again is overlaid by a seam of Coal

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about two feet thick. I have carefully measured all these beds, and have given their relative thickness and quality, both within and above the tree, with the tree itself *in situ*, in the accompanying Section, Plate 5, to convey a more correct idea than by description alone. A coincidence will be perceived between the band of shale within the tree, and that just named in the sandstone immediately above it; and it is much strengthened by the circumstance that the latter is also composed of thin plates of soft sandstone, with intermediate shale, and is also definitely and clearly separated from the hard sandstone above and below it. It is, however, fifteen inches thick, while that in the tree below is only ten inches, a difference to be explained in the sequel.

These general coincidences in the order and quality of the deposits within and above the tree, naturally lead us to inquire if they will not afford some clue to the circumstances under which it was interred. Had the tree been originally hollow, or even cellular within, the same blue shale that is deposited around it, would have forced itself into the interior; unless indeed while entire, there had been no aperture, or if its top had been above the surface of the water. In either case, the great lateral pressure of the surrounding water and muddy sediment, would have caused its sides to collapse. Most, if not all fossil trees found in an erect position, have retained their circular form, and moreover are filled with a material which differs from the surrounding matrix, and corresponds with an upper bed. This is the case with the specimen under examination; the base is twice the diameter of the upper part, and the whole trunk nearly round, so that it can have yielded but slightly to outward pressure, and none of the fine blue argillaceous shale which compactly envelopes it, seems to have penetrated within. These appearances indicate that the tree was originally solid; while, on the other hand, the inorganic matter which now represents it, affords indisputable evidence that it was, *at*

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some period, a hollow cylinder, which admitted the sediment in a soft state, and through a wide aperture, because these fossil trunks contain fern leaves, calamites, &c., often of considerable size, and with their beautiful markings uninjured. The question therefore arises, how these contradictory appearances can be reconciled; and I think a satisfactory solution may be found in the process already described, by which the solid wood of modern timber trees in tropical climates is removed, while the bark remains sound. I will just repeat that there is no real difficulty in applying this explanation to the fossils under consideration, on account of their upright trunks being surrounded by water, so long as their tops were above the surface and exposed to atmospheric influences, as already stated. The wood would be gradually removed, and when the exposed top was either broken off by further decay, or submerged by a second subsidence, the operation of filling would commence, and the sediment then contained in the water, would be simultaneously deposited within and above the tree, though at different levels. If any change took place in the nature of the sediment, it would be the same in both places, and so would the thickness of each bed, if the cylinder were of uniform diameter; but if of a conical shape, the introduced matter, having a wider area to cover than the aperture by which it was admitted, would consequently be thinner than its equivalent above. This will explain why the sandstone which forms the lower part of the tree is not so thick as the bed which surrounds its top, and which I take to be the same deposit. To the eye the sandstone within and above the tree in which the shale bands are inserted, appears to be precisely identical. The only difference between the shale bands is in their relative thickness, that within the tree being only ten inches, while that above is fifteen inches, and this is satisfactorily explained. In the former, the section is a vertical one, or nearly so, but in the latter, it is

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measured on the slope of the cutting, which inclines about thirty-six degrees towards the railway; and as the strata dip about seventeen degrees in a contrary direction, or inwards from the slope, it follows that the Section will be a diagonal of nearly one third greater extent than the vertical one, and consequently that the real difference, if any, is very slight. Besides, from the gradual tapering of the tree upwards, the aperture through which the sediment was admitted, would have a less diameter than the shale band itself; and moreover, no sediment from the water that was *below* the top of the tree could be introduced, so that both these causes would tend to reduce the thickness of the lower band. It is also necessary to bear in mind that when this shale-band was formed, the top of the cylinder must have extended upwards seven or eight feet higher than it does at present, as indicated by the dotted outline *d* in the Section, Plate 5. But on this assumption, another apparent discrepancy will arise, on comparing the relative thickness of the sandstone over the shale-band, within and above the tree. Its present thickness in the trunk is five feet six inches, and if to this we add about seven feet six inches to the top of the dotted line, it will exceed that of its supposed equivalent above, which may appear at first sight to be fatal to the view I have adopted. But I think it only proves that when the surrounding sediment had risen as high as the top of the cylinder, a good deal of what afterwards settled round it would find its way into the aperture, in addition to that derived from the water *perpendicularly* above it; the specific gravity of the sandy deposit would cause it to slip down and form a quaquaversal slope or funnel round the orifice, which as the sediment accumulated, would collect it from a continually widening area, and rapidly fill up the cavity.* It

* No indication of such an arrangement can be seen in the present instance, because the top of the trunk and its surrounding matrix for six feet

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may also be observed that the upper part of the tree is of a softer material and a bluer tint than it is below, shewing a correspondence with the gradual change from sandstone to shale in the bed above, and rendering it probable that the top of the trunk reached still higher than the point I have assigned it. Had that portion of it been fortunately preserved, it might have been possible, by comparing the diameter of the aperture with the capacity of the base, to have pointed out the level in the surrounding strata at which the interior began to be filled up. But as this is lost by the excavation of the slope, and as the extreme base, and probably the roots also have disappeared from the same cause, all that can be ascertained is that the tree became hollow about the period when the change in the deposit from the lower shale, to the sandstone above it, took place.

I have now shewn that the trunk of this fossil is a cast in sandstone of the original tree, and that it is composed of the same strata placed in the same order of succession, and with the same transitions, now abrupt and now gradual, as are found in the rock above it; I have accounted for this general correspondence, for several slight inequalities of thickness, and for the difference found in the material within the base of the tree, and in the imbedding matrix; I have offered strong evidence from the laws of vegetable physiology, that it was a dicotyledonous hardwooded timber tree, and the testimony of three scientific travellers, two of whom are distinguished botanists, that such trees in our own day, rapidly become hollow by the decay of their wood in hot humid climates, while their bark remains sound; and I have given an instance from the coal strata, of a fossil stem in which a portion of the original dicotyledonous structure was preserved among the inorganic matter that filled the inte-

in every direction have been removed in excavating the railway; but I mention it that observation may be directed to this point on any future discovery of upright fossil trees.

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rior. I am therefore of opinion, after a careful consideration of all the evidence adduced, that the tree in question, in common with numerous others found in similar situations, was a hardwooded solid timber tree, that it grew on the spot where it still stands, and after the first subsidence of the land, remained in an erect position with its top above the water; that it was converted into a hollow cylinder by the gradual decay of its wood, from natural causes still in operation; that when altogether submerged, it became a mould for the reception of sediment from the turbid waters, and was gradually covered up by subsequent deposits, preserving the exact form and character of its original woody surface, as the carbonized exterior has that of its bark; and that now, when at length it is disinterred after the lapse of countless centuries, it presents to us an exact cast or model in sandstone, of the trunk of a growing forest tree of the carboniferous æra.

Having dwelt so long on the appearances presented by this, the most important of the group, I shall merely add that all the other fossil trees are of similar sandstone, are imbedded in the same blue argillaceous shale, and stand in the same position on the thin bed of coal. No. 2, indeed, which is so striking from its enormous roots, seems to be intermediate between shale and sandstone, and to partake of both; it is much softer than the rest, and has yielded more rapidly to decay. This may be accounted for by supposing that from some cause or other, it became hollow at an earlier period than the rest, and was in a condition to receive the sediment at the commencement of the change from shale to sandstone. The small specimens called No. 3 and 4, had roots when first exposed, but being of shale they are now crumbled away.

There are one or two circumstances connected with these interesting fossils, which, though I shall not venture to lay any stress upon the deductions they may lead to, I may be

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allowed to mention, because if future observations on other specimens should enable botanists to make any approximation as to their age and rate of growth, they would form elements and possess a value they may not yet be thought entitled to. *I allude to the great size of the trees compared with the thinness of the bed of coal on which they stand*, and which it will be recollected, is not more than nine inches thick. If it be admitted that these trees were of solid timber, and grew in the vegetable matter from which this coal is derived, it is evident, that *at least* as long a period must have been occupied in its formation and accumulation, as was necessary for the trees to acquire their present size, and probably much longer. If we had any data by which to estimate the rate of growth of such trees in tropical climates in our own day, we might make a tolerably near approach to the time these fossils required in the probable climate of the coal æra to attain their present dimensions, and might thereby arrive at the minimum of time necessary for the growth and conversion into mould, of the vegetable matter in which they grew. In answer to my enquiries on this head, Mr. Schomburgh informed me that generally speaking, he thought a dicotyledonous tree, which, in temperate latitudes would require a century to attain to a given thickness, would only require from sixty to eighty years within the tropics. Doubtless the rate of growth of different natural families varies there as well as in higher latitudes; but as no precise observations have been published on this head, that I am aware of, I will take the oak of our own climate as a basis, because we know that on an average it requires about one hundred and fifty years to acquire the size of the large fossil, No. 1, which at eight feet high, measures two feet in diameter.* According, therefore, to Mr. Schom-

* In Loudon's Arboretum Britannicum, vol. 3, it is stated that the average circumference of five oaks of one hundred and twenty years old, was about sixty-one and a half inches, or a diameter of about twenty inches,

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burgk, a timber tree of this diameter would be about a hundred years old within the tropics at the present day; and for want of more precise data, it may be assumed that the climate of our own latitude during the carboniferous era, was somewhat similar, and that the fossil tree No. 1, was the growth of about a century. That period, therefore, on the lowest calculation, must have been necessary to produce as much vegetable mould as the tree required, even admitting that the tree was coeval with the earliest vegetation on the newly emerged surface. But it is more probable that some time would elapse before a sufficient quantity of vegetable mould would be formed for a young tree to take root in; nay, it is very possible there might have been a previous generation of similar trees on the same spot. So that under all the circumstances, it may be assumed that *a much longer period than a century* has been necessary to produce as much vegetable matter as is contained in a bed of coal nine inches thick.

Again, these fossil trees seem to me to afford some evidence as to the amount of shrinkage which vegetable matter has undergone in its conversion into coal. This will be better understood if I first describe the mode of growth of a modern tree. Let the dotted perpendicular line, *a*, in the diagram A, Plate 4, represent a young sapling, and the horizontal dotted line, *b*, the surface of the soil, in which its roots, *c*, *c*, strike out on each side. Let the scored outline of the same diagram represent the base of its trunk and main roots when it has become a full-grown tree, the upper part with the head being removed, and the stool divided perpen-

taken at six feet from the ground. Also that four oaks of sixty years old, had an average circumference of thirty inches, or a diameter of about ten inches, taken also at about six feet above the ground. It is also stated that a middle aged oak grows from an inch and one-third to one inch in circumference yearly, between its twentieth and its hundredth year; that it sometimes exceeds this measure, and in its second century falls within it.

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dicularly through the centre, so that the diagram represents a vertical Section of it. The lines in the interior that are parallel to the surface, are longitudinal sections of a few of the annual rings of new wood, which being successively deposited upon each other, cause the gradual increase in the diameter of the trunk. The axis of the roots is shewn by the dotted diagonal lines, *c*, *c*, which are continuations of those of the sapling. To understand this, it is necessary to say that in the roots of dicotyledonous trees, the chief increase of woody fibre is on the *upper* surface, or that which is nearest to the influences of the atmosphere and of heat, so that a transverse Section would have the appearance of the diagram, B, Plate 4, in which the axis (for roots have no pith,) is very eccentric, and very near to the under surface. This economy will explain the protrusion out of the soil of the roots of old trees at their divergence from the trunk, often erroneously attributed to the shrinkage or removal of the surrounding earth, or to the apparent lifting up of the whole tree. Let us now apply these laws of the growth of modern timber, to the fossil trees under consideration, from one of which (No. 2) the outline and proportion of the diagram I have been explaining, are actually taken. The main roots diverge from the trunk at an angle of twenty-eight to thirty degrees with the horizon, and are abruptly cut off where they rest on the surface of the coal, *d*, *d*. Under the centre of the trunk is a hollow vaulted space, *e*, fourteen or fifteen inches in perpendicular height from the surface of the coal. Now I think it will be apparent, from the angle of the divergent roots and their present position *upon* the coal, that the tree could not, when growing, have occupied a *lower* position than it does at present; probably a much higher one. It seems also evident that the surface of the soil, *b*, *b*, could not have been *lower* than it appears in the diagram, for had it been so, the base of the stem where the roots diverge in the sapling, would have been exposed

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and lifted out of the ground, which is what we never see in nature.* I believe I have kept within the truth in placing the original surface of the vegetable mould only three or four inches above the central vault. If, therefore, we add to this the height of the arch, fifteen inches, and nine inches more for the thickness of the coal, we have a total of twenty-seven or twenty-eight inches for the original depth of the vegetable matter, which in its consolidated state, as coal, is now compressed into a thickness of nine inches. It is therefore reduced into about one-third of its original bulk, and has lost two-thirds by shrinkage. This is probably the minimum, for if we take into account the rank and gigantic character of the Coal Plants, we shall easily admit that in decay they would rapidly accumulate a deep mould which would raise the surface much higher than I have assumed, and consequently that the actual shrinkage has been much greater. However high it might have been, the trees would sink gradually with the vegetable mould as it underwent decomposition, and would pierce it when become semifluid by fermentation, till they found a solid resting place at the bottom of the yet half formed coal.† The vegetable matter may therefore have occupied many times the bulk I have assigned to it, but could not have occupied less; and the greater the original bulk, the more considerable has been the shrinkage.

I offer these views with diffidence, being aware they may be thought by some to lie beyond the legitimate province of the geologist; but I wish no more value to be attached to them than they may seem entitled to in the estimation of those

* In the Manchester Botanic Garden, where the soil is light and deep, the roots of forest trees spread more or less horizontally, at a depth below the surface varying from one to eight inches.

† It has been already said that the roots do not penetrate the coal, but are abruptly cut off at its surface; and that the immersed portions have probably been acted on by the chemical changes going on in the surrounding vegetable mass, so as not to be distinguishable from it.

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most competent to decide. In geology, complete evidence can seldom be obtained, but by tracing insulated facts, as they present themselves, to their probable origin, and by examining their various bearings and relations, many an interesting problem may ultimately be solved, which at first sight may seem beyond our reach; and if we can at all facilitate the deductions of future observers, our feeble efforts will not be entirely useless.

NOTE.—While this sheet was passing through the press, I was asked by a very intelligent friend to explain how, on the supposition I have adopted, viz., that the decay of the wood of these fossil trees took place while they were standing *upright*, all traces of it should have disappeared, since it is reasonable to think it would be found in the shape of carbonaceous matter at the bottom of the cylinder. The objection is pertinent, but I think it may be removed by a due consideration of the conditions I have stated, i. e., that the top of the tree was *first* broken off at some height above the surface of the water, and that the process of decay was far advanced, if not completed, before a farther fracture broke down the trunk low enough to admit the water. The decayed wood, then lying in detached fragments at the bottom of the hollow cylinder, would be so buoyant, that it would immediately rise, escape through the orifice, and be floated off. In fact, the interior inorganic matter of these fossil casts is often mottled with carbonaceous fragments, shewing a fibrous woody structure; and it would be difficult to disprove that these are not portions of their own original wood.—J. E. B. 16th Aug., 1841.

A beautiful set of Models of these Fossil Trees, and of the Section of the Coal Measures, shewing them *in situ*, with the Railway, &c. &c., all drawn to scale and coloured, has been prepared by Mr. WM. BALLY, of Manchester, and may be had for a moderate sum.

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ART. VII.

On a WHITE FOSSIL POWDER *found under a Peat Bog in Lincolnshire, composed of the siliceous fragments of microscopic parasitical* CONFERVÆ. *By* J. E. BOWMAN, F.L.S. & F.G.S.

Read 7th November, 1839.

IF we take the Telescope or the Microscope, and survey those portions of Creation which lie beyond the reach of the unassisted eye, we are equally lost in wonder at the magnitude and distance of the one, or the minuteness of the other. The Telescope reveals to us worlds and systems so inconceivably remote, that imagination led on by science, fails to comprehend their immeasurable distances. The Microscope not only enables us to examine the hidden structure of organized forms upon our own globe, but brings into view living beings so inconceivably delicate and minute, that but for the evidence of our senses, their existence would be called in question. If there be one thing more surprising than another in the whole range of natural phœnomena, it is perhaps the vast extent to which both animal and vegetable life are carried downward in the scale of being. When we see an animalcule sporting freely in a drop of water, we feel as incapable of forming any distinct conception of the minute muscular fibres by which its motions are effected, and of the still smaller system of vessels by means of which it is nourished, as we are of the magnitude of the universe; and we are more perplexed in attempting to comprehend its organization, than that of a

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whale or an elephant. Yet Ehrenberg has discovered that the infusoria are provided with muscles, intestines, teeth, eyes, nerves, &c., though forty-one thousand millions of them might be contained within the space of a single cubic inch. Every naturalist is aware of the countless myriads of these creatures that swarm during summer in ditches and stagnant waters, and of the marine Polypi that exist in such inconceivable numbers in the seas of warm latitudes. These minute beings are endowed with the power of secreting lime from the sea water, and by means of it they build up a complicated calcareous framework beneath the ocean, which from a coral reef becomes first an island and then a continent; and after being the resort of birds and clothed with vegetation, is fitted for the abode of animals, and ultimately prepared for the reception of man himself. It can be proved that this process has been in operation from a very early geological period; many of the Transition or Silurian limestones are vast masses of coralloids and encrinites, immense coral reefs reared by polypes in ages inconceivably remote; while the carboniferous limestone, as well as every other of later formation contain abundance of their remains; so that these insignificant animalcules have performed an important part in the structure of existing continents.

It is not much more than three years since the distinguished living philosopher already named, astonished the scientific world by the discovery of animalcules in a fossil state. In the course of his extensive investigations, he found that a soft stone, the *Tripoli* of commerce, long used as a fine polishing powder, consisted almost entirely of the siliceous skeletons of microscopic animals, which being perfectly preserved, may be examined by the microscope, and compared with living species, with some of which they are identical. This stone, or powder, is found in such abundance in some countries that whole mountains are composed

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of it; he examined specimens from Sweden, from Bohemia, from Tuscany, and from the Isle of France, and found it everywhere composed of countless myriads of the exuviæ or cases of minute infusorial animalcules; whole races and generations of which must have lived upon the spot when covered by water. In Sweden and Lapland it is found in a pulverized state resembling flour, and is called *Bergmehl*, or *mountain meal*. In times of scarcity it is mixed up with grain and the bark of trees, and made into bread; and is superstitiously considered as a seasonable gift of the Great Spirit of the Forests. It would appear, indeed, that it has more than an apparent resemblance to meal, for Berzelius found, on analysis, that it contained a small portion of animal matter, though the bulk of it was pure Silica.

Another apparently similar powder has more recently been discovered, which stands in the same relation to plants, as that of Ehrenberg does to animals. The beings from which, in both, it is derived, are placed at the bottom of the scale of organic life, only one remove from inorganic matter, and where embryo vitality commences; and they constitute together a group which is the connecting link between the animal and vegetable kingdoms. Some of these forms are so ambiguous that the acutest naturalists who have studied them most, are still divided and uncertain as to which they essentially belong. The extremities of some shew moveable little points, which afterwards change into new individuals; are these ova, or gemmæ? and others have been observed to increase by separation; are these polypes, or viviparous vegetables? Many of the species emit an animal smell when burnt, by which it has been inferred they ought to be classed with animals; but this is only negative evidence, because various large *Algæ* of undoubted vegetable origin also produce a similar odour on being burnt. Wherever the line of separation may be

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ultimately drawn (which it probably never can) they form together a transition group, imperceptibly passing upwards on the one hand into the animal, and on the other into the vegetable kingdom; each successive division in the ascending scale, becoming more and more decidedly stamped with the characters of the one or the other, and in its advance, being endowed with a higher and more complex organization. But while just emerging from doubt and obscurity, there are some existing forms which may be safely referred to the animal and others to the vegetable kingdom, both still retaining the common character of being invested with a siliceous case or envelope, which is indestructible; analogy therefore would lead us to suppose that similar forms might also be found in the fossil state.

In Silliman's American Journal of Science for October, 1838, Professor Bailey states that he found in the neighbourhood of West Point, State of New York, a deposit of white powder eight or ten inches in thickness, and probably several hundred square yards in extent, buried about a foot below the surface of a small peat bog, which, on examination, was almost entirely made up of the siliceous shells of infusorial animalcules, among which were a few fragments of vegetable origin. He also found near the same locality, living infusoria in great abundance in small streams and stagnant pools, and nestling in wet moss on moist rocks; but most abundantly in bunches of Confervæ which constitute the green slimy matter so abundant in bogs and slow running brooks. They were accompanied by great numbers of minute parasitical Confervæ, by burning off the vegetable matter from which, and examining the ashes with a good microscope, numerous siliceous shells, both of the animalcules and the plants were discovered, and were found to be equally unchanged by fire or acids. Many of the forms of each were found to be identical with those in the fossil state.

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The knowledge of these curious facts stimulated scientific men to search for and examine similar depositions in other places; for it was not yet suspected that anything of a similar nature existed in Great Britain. In the Magazine of Natural History for July last (1839), Dr. Drummond of Belfast, announced the discovery, in Ireland, of a very light white earthy substance, found in considerable quantity on lowering the waters of Lough Island Reavey, by the Bann Company, under a covering of about a foot of boggy soil, and in other neighbouring valleys in the recesses of the Mourne mountains in the county of Down. He describes the powder, when dry, to be of the whiteness of chalk, but becoming brownish when wet; as light as carbonate of magnesia, which it much resembles, and without any admixture whatever of unorganized matter, or cementing medium. The specimen he received was a compact mass, and had a coarse and somewhat fibrous fracture, but could easily be pulverized; when rubbed between the finger and thumb, it had no grittiness, but seemed to be an impalpable powder; and when it was then blown into the air, it floated about almost like wood ashes. Magnified figures of this powder are given, consisting of six different shapes, but the bulk of it is stated to be long linear spicular bodies, with a small per centage of others of an oblong or square shape, or oval, or with swollen ends. This powder was not acted on by nitric, muriatic, or sulphuric acid, and was indestructible by fire. Now, it is a well known fact, that many families of vegetables, especially the Gramineæ and Caricès, take up a large quantity of Silica in a fluid state through their roots, and deposit it in an organized shape within and upon their stems and leaves. In fact, beautiful vegetable skeletons of such plants may be procured by burning away all the carbonaceous matter, after which a complete counterpart of the original structure, as white as snow, is left in the indestructible siliceous

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framework. It is also known that Silica, in considerable abundance, enters into the composition of certain tribes of Algæ, Confervæ, &c., and may be seen in their ashes, after burning, in an organized and unaltered state. On submitting some minute parasitic plants of these families to a red heat, and afterwards examining them in the microscope, Dr. Drummond found that the ashes of one of them, the Diatoma elongata, which abounds in a small drain in the neighbourhood of Belfast, consisted of oblong joints precisely similar to the spicular bodies that formed so large a proportion of the fossil powder from Lough Island Reavey, and he came to the conclusion that the latter is composed of the siliceous skeletons of portions of these minute vegetables, and analogous to what had previously been found in several places both in the old and new world.

As yet, however, it was not known that this highly curious, though apparently uninteresting powder was to be found in England; and this discovery is due to the researches and close observation of our indefatigable honorary secretary, Mr. E. W. Binney, though from being unacquainted with the character and structure of the minute and grotesque forms of the tribe of vegetables to which it owes its origin, he was not fully aware of its real nature. He informs me that so long ago as 1836, being then on a visit in Lincolnshire, he observed a whitish pulverulent substance on the sides of a deep ditch, which he at first took to be lime; but on examination, finding it to be quite different in its properties from that body, he supposed it to be of animal origin. The place where it was found is a portion of reclaimed peat bog, about four feet in thickness, lying on the Upper Red Marls, one mile west of the escarpment of Lias limestone in the valley of the Trent in Blyton Car, near Gainsborough. The peat was in a high state of decomposition, and had been under cultivation for some years. The white substance in question

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had been thrown out in widening the ditch, and originally occupied a bed varying in thickness from four to six inches at the depth of about a foot under the surface of the peat, and extending over an area of several acres of land. In some places the powder was mixed with portions of peat, but in others it was quite free from such admixture. When first dug up it was of a yellowish colour, and in the state of paste; but on becoming dry, it changed to a beautiful white powder that floated in the air on the slightest agitation, was tasteless, and bore a great resemblance to calcined carbonate of magnesia. Conceiving that it might be fatty matter in the state of Adipocire, he successively treated it with sulphuric, hydrochloric, and nitric acids, and afterwards submitted it to the action of heat, but by all these processes it remained unchanged; and he was thence led to believe it was Silica in an extremely minute state of subdivision. He next exposed it, under the action of the blowpipe, to an intense white heat for fifteen minutes; and treated it with the carbonates of potash and of soda, thus forming Silicates of these substances. He subsequently learned that a similar substance was found near Haxey, in the peat deposit of the neighbouring level of Hatfield Chase, in considerable abundance, and was informed by the farmers there, that wherever it occurred the soil above it was very poor and unproductive. This fact is a strong confirmation of its being Silica, such soils being proverbially sterile.

In this stage of his knowledge, Mr. Binney saw Dr. Drummond's account of the powder from Lough Island Reavey, to which I have referred, and immediately recognized the deposit of Blyton Car to be analogous. Indeed, it is remarkable how closely the two descriptions coincide; and it will be observed that in both cases, as well as in that from the United States, the powder was found *under peat*, and resisted the action of acids and of heat. He shortly

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afterwards procured a fresh supply from Lincolnshire, and submitted it to several friends; among others, he requested I would examine it closely, and communicate the result. The little acquaintance I had with the obscure, neglected, but pre-eminently beautiful and extraordinary tribe of the *Confervæ*, shewed me after the first inspection of the powder, the high probability of its connexion with them; and a reference to some specimens in my own herbarium, and to magnified figures of others in the works of Greville, Sowerby, &c., soon convinced me that it was indeed the accumulated remains of myriads of these minute aquatic plants, purified by the decomposition of all their original vegetable matter, and effectually secured from contact with other impurities by the superincumbent peat. The circumstance of its occurrence between two beds of peat may, I think, be explained on the supposition of a slight change of level, by which the lowest bed has been submerged, and the water in which the Confervæ flourished, has remained long enough to allow the present accumulation of their remains. In time, however, the water has been driven off by the increase of vegetables, which in their decay have formed the upper bed of peat, and covered up the powder. Such changes of level, the result of subterranean movements, are of frequent occurrence, and are familiar to Geologists.

As the tribe of plants which compose this department of our native Flora is not generally known, it may not be amiss briefly to sketch their characters. They are chiefly aquatic, and afford the strongest illustration of the fact, that not a spot on the globe has been left without some visible witness of that Almighty Hand that first projected it into space. If the summit of the most barren rock or exposed heath is clothed with lichens and mosses, scarcely visible without a magnifier, the waters also, both salt and fresh, swarm with a vegetation of their own, if possible,

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still more minute; the coral caves and deep recesses of the ocean, the crystal lake and stagnant pool, the rapid and sluggish stream, the pure and icecold rivulet of the Alps, the thermal waters and even the boiling Geysers of Iceland, are respectively the natural localities of plants peculiar to themselves, which would soon perish if transported into any other temperature. These are the *Algæ*, or *Confervæ*, many of which are conspicuous for the beauty and even splendour of their colours, and so strange and grotesque in form that they seem to have dropped down from some other planet; while each is admirably fitted for its place in the great chain of being, adapted for food to innumerable tribes of creatures, in figure as anomalous as themselves, and many of them of direct utility to man, either as food, in medicine, or in the arts. Some, which on account of the simplicity of their forms, are placed at the bottom of the vegetable scale, are so minute as to be invisible to the naked eye, except by the altered appearance they give to other larger species on which they grow in such prodigious numbers. To this division belong those which have furnished the fossil powder now described. Their figure and structure are so unlike ordinary plants, that some of the ablest naturalists have doubted whether they really belong to the vegetable world, and have confessed themselves unable to draw the line of distinction between them and the less highly organized animals, from which, however, they are equally dissimilar. Minute as they are, many of them secrete a hard transparent envelope or shell of pure Silica, which, as we have seen, is almost indestructible, and is composed of innumerable pieces of a square, rhomboidal, or oblong shape, united during life by vegetable matter, but in decay separating at the joints into detached independent portions, the lines of separation being as clear and sharp as though cut by a razor, and leaving no trace of their previous union. Dr. Greville's botanical character of

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them is, *that they are generally hyaline or transparent, rigid and fragile, in parallel series or circles, naked or imbedded in a mucous mass or gelatinous frond, and at length separating into definite segments.* I may here observe, that though mostly parasitical and attached to larger species, many of them float loose in the water in wiry entangled masses, or detached little points not larger than a pin head, but when magnified appear like radiated or starry globes. These probably lie at the bottom of the water till the season of fructification, when they rise to the surface for a few weeks, and are so abundant that the fluid seems impregnated with curd or fecula, so as to attract vulgar observation. I have witnessed this singular appearance for several successive seasons, about Midsummer, in the broad deep lake near Ellesmere, in Shropshire, where it is known as "*the breaking of the water*," as though the lake thus cleansed itself of its slimy extraneous matter. Some similar minute Confervæ appear annually on the Lake of Neuchatel, and attentive observation would probably detect them in other waters; and we can scarcely doubt but the same causes which deposited the powder under Lough Island Reavey and Blyton Car, are still in operation in favourable localities. The deposit is still going on in Lough Island Reavey; nor is it an improbable conjecture, that if ever, by a slight elevation, the lakes of Ellesmere and Neuchatel come to be drained off, the remains of floating and parasitical Confervæ may be found occupying a stratum along their former bottom, covered up by peat or bog moss.

It now only remains for me to state the result of my examination of the fossil powder from Blyton Car. Though so impalpable as not to be felt between the fingers, and so minute that with an ordinary lens no organization can be detected, a very high microscopic power shows it to consist of a mass of transparent squares or parallelograms of

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different relative proportions, the areas often plain, but frequently traced with many very delicate parallel lines or streaks, which either cover the entire surface, or only occupy the middle zone in one direction, leaving a broad plain transparent belt on each side. Some of the particles are linear and very long, with occasionally a longitudinal division; others having the same width are only one half, or one third, or one fourth the length; and the sides or edges of all, whether squares or parallelograms, are perfectly smooth, straight and uniform, and the corners rectangular and sharp. The bulk of the powder is, however, made up of irregularly shaped particles with roughish edges and rounded corners, though they are, evidently from their texture, of the same origin, and are but broken or comminuted fragments, which may have passed through the stomachs of fish, frogs, &c. The perfect particles bear a very close resemblance to minute crystals of various salts; and, to a certain extent, they may, without impropriety, be supposed to be formed in a similar way. Crystallization is a process which acts on, and aggregates together by fixed laws, the purer particles or atoms of inorganic matter, suspended in fluids, and seems to be the first step by which they are refined, and after farther chemical changes, prepared as it were for passing into an organic form. Therefore, while these atoms are subject to the laws of crystallization, they may be considered as in an intermediate or transition state between organic and inorganic matter; and in this view the siliceous powder, now under consideration, may be said to partake of the nature of crystals. The atoms of which it is composed, are, in fact, an essential portion of an organized body in its lowest and simplest state, in which the vital principle has indeed been developed, but has not yet acquired sufficient energy to liberate them from the dominion of the laws of crystallization.

In the accompanying figures (see plate 6, fig. 1), I have

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sketched all the different forms that have come under my notice; many of them agree with those figured from Lough Island Reavey, though I have not detected all that were found there. Neither have I perceived among them any that could be taken for the siliceous skeletons of animalculæ, though it is very probable that some such may lurk unseen.

After the evidences I have now brought together, I think the conclusion is irresistible, that this impalpable powder is a mass of countless myriads of the siliceous skeletons of many generations of minute *Confervæ*, either identical with, or very nearly allied to, those of existing *Diatomaceæ*.* If the highly magnified figures of it here given be compared with the separate portions or joints of the plants referred to in botanical works, the closest connexion will at once be apparent. The Botanist and the Geologist may each congratulate himself that these minute particles have thrown new light upon an obscure corner of the wide field of his own researches; for while the former may prove their close alliance with existing vegetables, the latter may claim for them a place in the Fossil Flora, and rank them with the splendid discoveries of Ehrenberg.

* Among many other kindred forms, the reader is referred to Echinella fasciculata, Grev. Cryptog. Flora, plate 16, Achnanthes unipunctata, pl. 287. Exilaria flabellata, pl. 289, Ex. fulgens, pl. 291. Diatoma flocculosum, Engl. Bot. t. 1761. Diat. Biddulphianum, t. 1762, &c. &c.

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ART. VIII.

On the Fossil Fishes of the Pendleton Coal Field. *By* E. W. BINNEY.

Read 29th October, 1840.

AMONG the many geological phenomena which the neighbourhood of Manchester exhibits, none, perhaps, possess more interest than the Fossil Fishes. The various strata of indurated clays, sandstones, and limestones occurring in our coal field, all in regular and determinate order, enable us to form some ideas of the operation of those physical agents, which during the lapse of countless ages have disintegrated the pre-existing rocks, and transported their component parts to the places where they now are found, and, the intensity and duration of their forces. The remains of the vegetable kingdom, found, at a depth of thousands of feet, entombed in beds of coal and their accompanying rocks and shales, shew us the characters of the luxuriant forests and delicate plants that once flourished on and adorned the surface of the ancient world; the mighty revolutions that have taken place in the relative positions of land and water; and the vast periods of time that it must have taken for their production. It is, however, from the examination of Fossil Fishes, the former inhabitants of the deep, that we must look for the first animated beings of the higher order that appeared on the face of our globe, and sported in its primeval waters. In these researches, to use the words of Dr. Buckland, "we introduce an additional element into geological calculations; we bring an engine of great power, hitherto unapplied to bear on the field of our

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inquiry; and seem almost to add a new sense to our powers of geological perception."

No class of fossils has received less attention from the Palœontologist than the remains of fishes. This has arisen, probably, from the imperfect state of the science of recent Ichthyology, in which, until taken up by the great Cuvier and his celebrated successor, Professor Agassiz, little had been done. No doubt, the inaccessible abodes of fishes rendered the study much more difficult than that of terrestrial animals.

The chief characters by which Cuvier arranged this class of the *Vertebrata* were the number and position of the fins, the gill covers, the teeth, and the branchiostegous rays. This method of arrangement, although admirably calculated for the classification of recent fishes, would not serve to any great extent in the examination of fossil specimens, the majority of which are mere fragments of bones and detached scales.

The fact of the formation of so large a portion of the crust of the globe beneath water, would lead us on first thoughts to expect the discovery of traces of the former existence of fishes, wherever we find the remains of *mollusca* and *conchifera*.

We will now consider shortly the remains of recent fishes. When the bottoms of lakes and pools that formerly abounded with fishes, as well as *testacea*, are examined, those of the former are rarely to be met with, although we generally discover an abundance of the remains of the latter. Whether this absence arises from the speedy decomposition of their bodies, or the fact that few of them die natural deaths owing to their predatory habits, it is difficult to say. It is very probable that their remains may have been devoured by the myriads of small crustaceous animals inhabiting fresh water. Whatever may be the cause, it is certain, that their skeletons, either separated or entire, are rarely to be found,

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even in places where fish were known to have formerly abounded.

Professor Agassiz, after great research and patient investigation, has come to the conclusion that fishes may be classed from the characters of their scales. So great is this distinguished naturalist's knowledge of the comparative anatomy of fishes, that he is reported to have announced not only the genus, but even the species, of an individual, from the examination of a single scale. This mode of classification is peculiarly adapted to the fishes of the coal formation, many of whose scales, thickly coated with enamel, remain, when all the rest of the skeleton has entirely disappeared.

The following are the new orders into which Agassiz divides his class of fishes (as taken from Dr. Buckland's Bridgewater Treatise, vol. I. p. 269).

First order. *Placoidians* (from πλαξ, a broad plate). Fishes of this order are characterised by having their skin covered irregularly with plates of enamel, often of considerable dimensions, and sometimes reduced to small points, like the shagreen on the skins of many sharks, and the prickly tooth-like tubercles on the skins of rays. It comprehends all the cartilagenous fishes of Cuvier, excepting the sturgeon.

Second order. *Ganoidians* (γανος, splendour). The families of this order are characterised by angular scales, composed of horny or bony plates, covered with a thick coating of enamel. The bony pike (*Lepidosteus osseus*) and sturgeon are of this order. It contains more than sixty genera, of which fifty are extinct.

Third order. *Ctenoidians* (κτεις, a comb). Families of this order have their scales toothed on their posterior margin. They are composed of laminæ of bone, but have no enamel. The scales of the perch are a familiar example.

Fourth order. *Cycloidians* (κυκλος, a circle). Families

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of this order have their scales smooth and simple at their margin, and often ornamented with various figures on the upper surface. These scales are composed of laminæ of horn or bone, but have no enamel. The herring and salmon are examples.

I have described the characters of all the four orders for the purpose of shewing M. Agassiz's system of classification. The two first, namely, the *Placoidians* and the *Ganoidians*, are the only ones which relate to the Fossil Fishes of the coal measures; the latter never having been found, according to Agassiz, below the chalk formation. Mr. Strickland and some other geologists assert that they have found the remains of *Cycloidians* in the Lias.* If this be true, probably their absence in the coal measures is owing to the perishable nature of their scales, rather than their non-existence during the period those strata were formed.

LOCALITIES OF FOSSIL FISHES IN LANCASHIRE.

The remains of fishes in our coal measures are chiefly of the *Ganoid* order. Detached scales and fragments, and, more rarely, entire specimens, are found, from the lowest workable mines in the series up to the Ardwick Limestones, now generally considered to be the highest portion of the coal measures. The strata in which they generally occur, are highly bituminous schists, provincially known by the name of "*Black Basses*," and in the various beds of cannel. This probably is the reason why the remains so long escaped the attention of collectors, since being in search of fossil plants of which these beds are for the most part destitute, they consequently have not examined them with so much care as the light coloured binds, which are

* Since this Paper was read, I believe that Mr. Strickland, with the honest candour of an ardent investigator of truth, has admitted that he was mistaken.

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remarkable for the number and beauty of the plants that they contain. I myself have found teeth, and scales (probably belonging to the genus *Diplopterus*) in the black shales, above the small coals lying immediately above the Upper Millstone Grit cut through in forming the tunnel of the Manchester and Leeds Railway, at Summit, near Littleborough, mixed with remains of the Pecten *papyraceus*, and Goniatites *Listeri*, shells generally considered to have belonged to creatures formerly inhabiting the ocean. Mr. William Peace of Haigh, near Wigan, has collected splendid specimens of the genera *Megalicthys*, *Holoptychius*, *Diplopterus*, *Ctenoptychius*, and *large dorsal rays*, from the cannel mines of the Earl of Balcarres at Haigh, all in a most beautiful state of preservation, being converted into brilliant iron pyrites. Mr. Williamson, in papers read at the meeting of the British Association at Liverpool, and before the Geological Society of London, has described specimens of the *Palæoniscus*, *Holoptychius*, and other genera, from the bituminous schists of the Black and White Mine at Peel, and others from the Bradford coal field, and the Ardwick Limestones; and I may here mention, that Mr. Francis Looney, F.G.S., many years ago, noticed the remains of fishes in the two last named localities. The specimens I have collected are from the Pendleton coal field, a district that has not been examined by any of the above named gentlemen, although it affords the most entire remains that have as yet been discovered in this county. It is to this locality that I shall confine my observations on the present occasion.

They will be comprised under the following heads, namely, a slight description of the Pendleton coal field, a notice of the place where the fossils occur in the mine; an enumeration of the genera, the state and condition in which they are found, and conclude with some remarks

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on the probable cause of their occurrence in this particular locality.

DESCRIPTION OF THE PENDLETON COAL FIELD.

(See Plate I. *Fig.* 3.*)*

The portion of the great Lancashire deposit, generally known by this name, is the extreme southerly part of the wedge-shaped mass, commencing at a point near Whit Hall, Pendleton, and gradually extending in width, until it joins the main deposit at a little to the north-west of Giants' Seat, near Ringley. On its strike it runs to Bury Lane and Worsley. Both on its rise and dip, and south strike, it is surrounded by members of the New Red Sandstone formation. Its north-western boundary, the great Irwell fault, estimated by some to be a down throw of near one thousand yards, runs about thirty degrees west of north. This fault can never probably be truly estimated, at Pendleton, without driving through it at the new works of the Pendleton Coal Company, and ascertaining what the measures are on the other side; an undertaking of great danger, owing to the uncertain nature of the ground. At Clammerclough, near Ringley, the thin bed of coal worked by Mr. Dorning is nearly on a level with *Ellam's* mine, therefore, if the latter coal is identical with the *Four Feet* at Worsley, the depth of the fault is there about seven hundred and fifty yards, that being somewhere about the estimated distance between the two mines.

The general dip of the measures at Pendleton is at an angle of about eighteen degrees, to the south-south-west. The only seams worked in this neighbourhood, until the commencement of the new works of the Pendleton Coal Company, were the *Yard* and *Four Feet* mines. Whether these beds, as is generally supposed, are the same as the

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Charlotte, and *Four Feet* mines of Bradford, has never been correctly ascertained; their continuity can never be proved, owing to the great faults which separate the two fields, and the only ground for the conclusion, is the great resemblance of the two *Four Feet* mines. The following is a section of the measures at the Old Engine Pit at Agecroft Colliery, kindly furnished me by James Knowles, Esq.:—

	yds.	ft.	in.
Soil, Sand, Clay, and Soft Metal	15	2	0
Rock	11	2	0
White Earth	1	2	0
Coal	1	0	1
Chitter	1	0	2
Rock	34	0	0
Blue Leys	5	2	0
White Earth	1	2	0
Iron Band	0	0	3
Rock Warrant	3	0	0
Rock Bands	3	0	0
Rock	3	0	0
Blue Leys	5	0	0
Iron Bands	0	0	3
Black Stone	0	0	5
Rock	2	0	0
Blue Leys	2	0	0
Black Bands	0	0	6
Rock	0	2	6
Warrant Earth	2	0	0
Rock Warrant	0	2	0
Blue Leys	1	2	0
White Earth	3	1	0
Black Bass	0	1	0
White Earth	1	2	0
Coal	0	0	6

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	yds.	ft.	in.
Warrant Earth	2	2	0
Rock	0	2	6
Blue Leys	1	0	0
Rock	0	2	0
Blue Leys	5	2	6
Black Bass	1	0	0
White Earth	1	0	0
Black Bass	0	1	3
Coal	1	2	0
Total	116	1	11

The sinkings at Mr. Fitzgerald's old shafts, which are considerably deeper than those at Mr. Knowles', have not been preserved, but from their proximity to those of the last named gentleman (being only about three hundred yards to the south), they are probably in a great measure the same, with the exception of the roof. At the former mine, instead of the bass roof, there is one of fire clay; but a comparison of the two will best shew the difference.

Mr. Knowles'.

	yds.	ft.	in.
Blue Leys	5	2	6
Black Bass	1	0	0
White Earth	1	0	0
Black Bass	0	1	3
Coal	1	2	2
Clay Floor.			

Mr. Fitzgerald's.

	yds.	ft.	in.
Blue Leys	7	1	0
Black Bass	0	1	0
Very Black Bass	0	0	8
Ironstone	0	0	2
Impure Cannel	0	0	3

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	yds.	ft.	in.
Cap Coal	0	0	10
Fire Clay	0	1	4
Coal	I	1	0
Clay Floor.			

In Mr. Knowles' mine the fire clay on the top of the main coal is scarcely perceptible, but as the measures proceed to the south, through the workings in Mr. Fitzgerald's mine, it gradually increases, until at the extreme boundary of the last named mine it reaches a yard in thickness.

Both the fire clay and the floor of the *Four Feet* coal are full of the Stigmaria *ficoides*.

Very few remains of fishes are to be found in the bituminous schists of Mr. Knowles' mines; and what do occur, are detached scales and bones. None of the specimens have ever been found in the main coal, fire clay, or cap coal; but they occur in the impure cannel, the Black Bass, or the Ironstone band, most plentifully in the lower portion of the Black Bass. However, this bed does not yield them for any great thickness, probably not more than eight or ten inches above the Ironstone. Immediately after the fishes cease to be found, in the higher part of the Bass, numbers of an undescribed shell, resembling an *Avicula* (by some gentlemen supposed to be an *Unio*, see plate V., fig. 23) occur, but they are rarely, if ever, met with together. As soon as these bivalve shells make their appearance, not only do the remains of fishes cease, but the basses become less bituminous. Where *Coprolites* abound the remains of fishes are scarce. No traces of *Cypris*, or *Microconchus*, have as yet been met with, although they are found, in great abundance, higher up in the measures, about twenty yards, as proved in the recent shaft sinkings at Mr. Knowles' new pit.

The place in the mine where the fossils were found is in the lower part, at a depth of about three hundred yards

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under the Valley of the Irwell. However, they are not confined to this part alone, having been also found in the *rise* portion of the mine.

None of the specimens contain any of their original carbonates, and phosphates of lime, or other original parts, these having been entirely removed, and a cast of them in bright bituminous schist substituted. The parts which consisted of enamel, such as the outside of the teeth, spines, and scales, usually present a much brighter appearance than the bony parts of jaws, &c. That these parts did consist of such matter is clearly proved by the fossils occurring in the Ardwick Limestones, where the original phosphate of lime remains in the specimens. The remains of the fishes consist principally of the *Ganoid* order, and of the genera *Holoptychius*, *Platysomus*, *Palæoniscus*, *Cœlacanthus* (nearly entire specimens of all of which I have obtained), *Megalicthys*, and *Diplopterus*. Those belonging to the *Placoid* order, are the *Gyracanthus*, *Ctenodus* (?), *Ctenoptychius*, and *Diplodus*.*

It is not my intention to give a full description of the various genera and species, but merely to do little more than enumerate them. All my specimens of value are in Professor Agassiz's possession, and will be described by that celebrated ichthyologist in his great work "*Recherches sur les Poissons Fossiles.*"

MEGALICTHYS.

The remains of this extraordinary genus of sauroid fish are not very common in the Pendleton coal field, although found in abundance in the Ardwick Limestones, and Bradford coal measures, in the ascending, and the cannel of Wigan, in the descending series of the carboniferous strata.

* For the drawings to accompany this paper I am indebted to the kindness of Captain Thomas Brown, F.L.S., M.W.S.

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Detached scales, and a large tooth exceeding an inch in length, obtained by myself, and several teeth found by Mr. Ray, are the only specimens that have been met with in this locality. They all belong to the species *M. Hibberti.* From the interest excited in the geological world by the discoveries of Dr. Hibbert, at Burdiehouse, who considered the remains of this creature to belong to a saurian, until Professor Agassiz corrected the mistake, I shall give a a short description of the fish as far as its detached scales and fragments yet found will allow. The best specimens that have hitherto been discovered in England, are those of the heads and scales in the Museum of the Leeds Philosophical Society, and the collection of Mr. William Peace. The head is broad and large, and has more the appearance of a saurian than a fish; it is covered with strong plates of bone coated with enamel and thickly overspread with small punctures; the jaws are short, smooth, and flat, and the teeth, which are of several sizes, all of a sharp conical figure, slightly curved, fluted at the base, but plain at the top. Dr. Buckland, at page 44 of vol. 2 of his Bridgewater Treatise, states "that in the Megalicthys and Holoptychius, the structure of the teeth, large and small, was precisely the same as in the large and small teeth of the Lepidosteus *osseus*, both as to the hollow internal cavities and the external flutings towards the base, and also as to their mode of growth by ascent of fibrous matter from the bony substance of the jaws, and not from roots placed in deep alveoli, as in many saurians." Plate V., figs. 1 and 2, represents the exterior and interior surface of the jaw of a very young individual found in the Derbyshire coal field. Plate V., fig. 3, represents the upper part of a tooth of the *M. Hibberti*, from St. George's Colliery, Bradford, the lower part shewing the flutes having been broken off.

The scales vary much in shape, those from the back of the fish being nearly circular, while others on the sides and

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under parts of the fish are angular, nearly approaching to rhomboids; both, however, have their posterior edges marked by a deep furrow, and their surface covered by a strong coat of enamel, thickly punctured with small orifices. (See plate V., fig. 4.) The under side of the scales presents a slightly convex surface with a ridge, which seems to have attached them to the body of the fish, as in plate V., fig. 5. The scales overlapped each other like the plates in old scale armour. The position and number of the fins have not yet been fully determined. In a paper read by Dr. Hibbert, at the Royal Society of Edinburgh, in 1835 (see Jameson's Edinburgh New Philosphical Journal. Page 383, vol. 18.), is the following extract from the M. Agassiz's communication to that gentleman:—"With regard to the alleged saurian remains M. Agassiz was induced to consider them sauroid, and assigns them to a large sauroid fish akin to the extant Lepidosteus. In the form of its teeth, and in the very near resemblance of its scales to those of a reptile, the Lepidosteus agrees with the crocodilean families. Nor does this general correspondence fail even with regard to the internal structure of the animal. Agassiz has described the result of an investigation of the swimming bladder of a specimen of the Lepidosteus *spatula*, preserved in spirits, from the dissection of which he was enabled to demonstrate, not only that it is a real lung, but even that it approaches closely to the structure of the lungs of reptiles, having characters in common with the lungs of salamanders, and of the reptiles improperly called doubtful reptiles. The lung or swimming bladder of the Lepidosteus is not only cellular but has also a trachea which extends the whole length of its anterior surface and communicates with a glottis surrounded by ligaments, intended to open and shut it, constituting an apparatus more complete than that of many reptiles. M. Agassiz also adds that the heart had not the appearance of that of a common fish; it is destitute of the

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inflation named bulbus *aorticus*, so characteristic of fish, and hence has much more the appearance of a reptile."

"With this fish, in its well marked external characters, M. Agassiz has compared the sauroid relicts discovered at Burdiehouse, and in this enquiry he has been assisted by an entire head of a large fossil fish preserved in the Museum at Leeds. From the aid thus derived he has been enabled to establish a new genus under the name of Megalicthys."

HOLOPTYCHIUS.

This fish occurs in great abundance at Pendleton, and several entire specimens have been discovered of individuals, from four to six inches in length, while detached scales, and enormous jaws, attest the former existence of individuals ten and twelve feet long. Its whole figure resembles that of a true fish more than that of the *Megalicthys*. The head appears to have been more elongated, covered with strong bony plates, and coated with enamel, but apparently not so thick as those of the last-named fish, and the gill covers are much better defined. The jaws are very strong and powerful, and their outsides present a very rugged surface when compared with those of the *Megalicthys*. The teeth are inserted into the jaw bones in the same manner as those of the *Megalicthys*, and consist of finely striated, sharp, falcated cones of several sizes. Each side of the upper jaw contains one large and about twenty-six smaller teeth, the former being placed at its anterior extremity. Fig. 6, plate V, represents the upper jaw of the small one, which is a new species. The sides of the lower jaw contain six large teeth and about twenty smaller ones in each. Figs. 7 and 7*a*, plate V, represent the teeth of the Holoptychius *sauroides*.

The scales consist of strong bony plates, arranged in concentric folds, and have their external surface coated with

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enamel; a fine fringe edges the lower part of the scale, which portion is also deeper and more irregularly punctured than those of the *Megalicthys*. Their shape varies much, those on the back being nearly circular, others on the sides (many of which display the mucous duct, as in fig. 10) cordate, and those on other portions elongated and irregular ovals. (See plate V. figs. 8 and 9.) The opercular and other scales when first exposed to light have an iridescence similar to that of the scales of some recent fishes, but on exposure to the atmosphere it soon disappears. They appear to have had pectoral and dorsal fins, which my specimens unfortunately do not distinctly shew: the ventral fins are placed considerably behind, and have a strong spiny ray coated with enamel in the fore part of each; the rays in these fins are fifteen in number: the two anal fins are destitute of spines, and are placed very near the caudal: this latter fin has the vertebral column prolonged, at its extremity, into a single lobe, which reaches to the upper extremity of the fin, a character so common to the fish found in the ancient strata, and like that of the sharks and sturgeons of the present day.

PALÆONISCUS.

Specimens of this genus, named the Palæoniscus *Egertoni*, by Professor Agassiz, are found in the Pendleton coal field; but they are not common. The best hitherto met with is one which shews all the bones of the head and the various shaped scales, having rough tesselated outer surfaces, some nearly rhomboids, and others acute angles. Fig. 11, plate V, represents the *under* side of one of the scales from the middle of the body, and fig. 11*a* the same side of one of the scales from near the tail. These display the beautiful manner in which the tooth of the one fitted into the notch of the other; but all the vertebræ and fins are wanting. Another specimen in my possession shews

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the tail to be forked, having the vertebræ prolonged into the upper lobe, as well as the two ventral fins, fringed with small rays, placed nearly opposite the dorsal. The jaws are curved and deep, being armed with sharp conical teeth of a nearly uniform size, inclining from the front. (See plate V. fig. 12.)

DIPLOPTERUS.

Scales and jaws of a fish of this genus are sometimes found. The former very much resemble those of the *Megalicthys*, except being smaller and having a plain outside surface without any groove. The latter is long and tapering, and armed with sharp teeth. (See plate V. fig. 13.)*

PLATYSOMUS.

A fish of this extraordinary genus, nearly entire, two inches and a quarter long and one inch and three-quarters broad, as well as a larger one, were both found by myself. It appears to have been a flat fish, somewhat resembling the Flounder in figure. The head is small, and its jaws are armed with small curved, conical teeth, set very closely together. The opercular scales and branchiostegous rays are well developed, and are not unlike those of the above-named fish. The scales are very remarkable; their shape being a long narrow oblong, coated with enamel, having a ridge running near the edge of the anterior portion, while the end is pointed and fits into the notch of the adjoining scale, something in the manner of the *Palæoniscus*. (Plate V. fig. 14.) Most of them are four, but some are even six times broader than long. The under surface of the scale presents a deep furrow below the external ridge. (Plate V. fig. 15.) The fins are not well pre-

* I am not quite certain as to this jaw being that of the *Diplopterus*.

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served in my specimens, but the dorsal appears to have extended nearly to the caudal. This last appears to be more symmetrical than that of the *Holoptychius*, still the vertebræ are prolonged into the upper lobe. The ventral is only slightly shewn. From the scales and other characters of the fish, it is probable that it lived at the bottom of the water.

CÆLACANTHUS.

Two entire specimens of fishes of this genus have been found. The largest is five inches, and the smaller about two inches long. The head is large, and the operculum is covered with raised dots. No traces of the jaw have been clearly recognised. The scales are difficult to distinguish, but some appear to be nearly cordate, while others are more angular, as in plate V, fig. 16. Both, however, are coated with enamel, and have their exterior covered with slightly waved lines. The dorsal fin is large, and extends from the middle of the fish to the caudal; it is armed with many sharp curved spines. The pectorals and ventrals are large and strong, and, as well as the caudal, are furnished with rays.

GYRACANTHUS.

Large bony rays of a fish of this genus are found detached. The fragment in my possession, three inches long and one inch in diameter, is probably the Gyracanthus *formosus* of Agassiz. The generic characters, according to this distinguished naturalist, consist in the disposition of the oblique corrugations which emboss the surface. These are ridges and deep furrows passing down in an oblique direction from the middle of the anterior surface of the ray towards the hinder extremity, and abut against the sides of the posterior medial line with their longitudinal furrows. This fish belongs to the *Placoidian* order, and to the family

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Cestraciontes, so named from their approach to the *Cestracion* of New Holland. The rays were attached to the dorsal fin. The fish being of a cartilaginous character, all its bones seem to have perished, and therefore little is known of its structure.

DIPLODUS *GIBBOSUS*.

Detached teeth are found in this locality. They have three prongs of irregular sizes, springing from a solid oval base of bone, those on the outer sides being the largest, and the central one much smaller, all thickly coated with enamel. (Plate V. figs. 17 and 18.) From the shape of the base, in which two orifices for the insertion of blood vessels appear, most probably they were inserted into cartilage.

CTENOPTYCHIUS.

Detached teeth of this genus occur at Pendleton. Like those last described, they, no doubt, belonged to a cartilaginous fish. They consist of solid pieces of bone, coated with enamel, having their edges toothed like a comb. Fig. 19, plate V, represents the *apicalis*, figs. 20 and 21 the *pectinatus*, and fig. 22 a *new* species.

CTENODUS (?).

A palate with a rough triturating surface is found, but whether it belongs to this genus it is difficult to say. Specimens of the four last described genera are rare at Pendleton when compared with the number found at Ardwick and Bradford, but they generally are met with near together. Whether they have belonged to one fish, or to different individuals, it is difficult to say; but, on comparing the three teeth with those of the Anarrhichas *lupus*, or wolf fish, it does not seem impossible, as the three kinds of teeth of that fish are fully as different in their characters as these.

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The condition of the fishes (many of which, especially those in the deposit of very black Bass, are perfectly entire, with their fins extended and not a scale displaced, except from the pressure which the bodies have been subjected to, from the overlying strata, when in a soft state,) seems to prove that they died on or near the places where they are now found, and that they have not been brought from a great distance.

The total absence of *mollusca*, and *crustacea*, in the strata where the specimens are found, appears to indicate, that the water from which they were deposited was not much fitted for animal life, as both shales, above and below the schist where the fossils occur, teem with remains of a *Cypris* and *Microconchus*. Wherever these latter occur no entire fishes are to be met with, they having doubtless consumed all the edible portions, and scattered the scales and bones. The analysis of the shale shews that the water in which it was deposited was probably of such a deleterious character, from the quantity of decayed vegetable matter it contained, as to prevent the existence of fishes *mollusca* or *crustacea*.*

The bodies of fishes, after death, float or sink, according to their specific gravities, the causes of their dissolution, and the density of the fluids in which they are immersed; those that have been killed by acrid poisons, and have had their intestines inflamed, nearly always immediately float

* The following is an analysis of the very black bass, made by Mr. John Dale, chemist, of Manchester.

Bituminous Matter	16 per cent.
Oxide of Iron	3 ,,
Silica	18 ,,
Alumina	59 ,,
Water and Loss	4 ,,
A trace of Oxide of Manganese.	
	100

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on the water. In my own experiments, I have found that one of the common gold fish (Cyprinus *auratus*, Linn.), living in clear spring water, after dying a natural death, sunk to the bottom and remained there about ten hours, the temperature being 60 degrees Farenheit; at the expiration of that time it rose to the surface and floated. Specimens of the common rough tailed stickleback (Gasterosteus *trachurus*, Cuv.), that died from want of food, at a temperature of 50 degrees Farenheit, also sunk to the bottom and remained there, while individuals of the same species, at the like temperature, on being immersed in tan liquor, died in ten minutes, and floated on the surface; these, however, upon being transferred into fresh water, sunk and remained at the bottom. From my experience of the influx of water highly charged with decomposed vegetable matter into streams abounding with fishes, as in the case of the draining of peat bogs into sluices of fresh water, in our climate, I am led to believe that the individuals thus destroyed, after remaining at the bottom a few hours, have their bulk distended by the generation of gases, produced during decomposition, and (not having been covered with a thick deposit of slime or mud, thrown down from the waters, so as to prevent their rising,) float on the surface until the gases escape. The parts soon afterwards separate, and the scales and bones then descend to the bottom, according to their relative specific gravities. The finny tribes generally abandon the streams so contaminated as fast as possible. I have known places in the low lands of Lincolnshire, adjoining the banks of the river Trent, formerly abounding with fish, suddenly become destitute of them from this cause. Indeed, the instinct of self-preservation, so generally exhibited by fish, convinces us, that they would desert such places as soon as practicable. In addition to this, the bottoms of recent fresh water pools give us no evidence of the deaths or entombment of entire fishes, in the ordinary

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course of nature. The irruption of the sea into fresh water lakes causes great destruction of fish, as also does the sudden bursting of peat bogs. On the elevation of the bed of the ocean by submarine volcanoes, as in the case of Graham's Island in the Mediterranean Sea, where it was stated that vast numbers of fishes were destroyed, and many of them probably buried in the mud thrown down from the turbid waters, a like effect would be produced,* but these effects arise from sudden catastrophes and extraordinary causes.

Under these circumstances, it is not unreasonable to conclude, that the fishes, in the shales alluded to in this Paper, were quickly destroyed by some sudden catastrophe, without having a chance of escape; for we can scarcely imagine that they would willingly enter, or even remain, in such a poisonous fluid as it is probable the water was in which the shales were deposited. It also appears probable, from the state of preservation in which the fishes are found, that they sunk to the bottom on their death, and were speedily covered by the black mud now forming the Bass, which prevented their rising to the surface, as they otherwise would have done.

As to the nature of the water in which the shale was deposited. The remains of the *Megalicthys*, which Professor Agassiz considers as allied to the recent *Lepidosteus*, a decided fresh water fish, seems to militate against the fact of their having been deposited in salt water, whilst the *Platysomus*, *Palæoniscus*,† and the remains of *Cestra-*

* At some of the recent explosions conducted by Col. Pasley for removing the wreck of the *Royal George*, near Spithead, numbers of fishes were destroyed.

† The genera *Palæoniscus* and *Platysomus* (and probably the *Cœlacanthus*) have both been found in the Marl slate, one of the lower deposits of the New Red Sandstone formation at Midderidge and East Thickley, on cutting the Stockton Railway. (Vide Professor Sedgwick's Paper on the Magnesian Limestone. Geological Transactions. Second Series. Vol. III. p. 77.

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ciontes, and other fish allied to those now generally found in the sea, seem to indicate a marine origin; but from the evidence of the organic remains, it is most probable that they were the inhabitants of salt water. I believe it is the opinion of Professor Agassiz that the strata forming our coal measures were all deposited from materials suspended in salt water, notwithstanding the general opinion that the Unio *acutus* and the *Cypris* were clearly indicative of a fresh water origin.

According to the opinions of Dr. Lindley, Mr. Bowman, and other eminent botanists, the Fossil Flora of our coal fields clearly indicate that the plants grew in a climate, at least fully equal to that at present existing within the tropics, and on land near to, or adjoining the ocean. Accordingly, we must look to operations which are now going forward in tracts of low land, covered with rich vegetation, within the torrid zone, for the formation of strata resembling those in which the fishes occur. Now, Mr. Hawkshaw, F.G.S., a member of this Society, in his work entitled "Reminiscences of South America," at p. 194, speaking of Venezuela near the coast, states "that in those parts of the country that are perfectly cleared, drainage is of less consequence, the sun is ardent, and water is soon dried up by evaporation; but in the wooded districts it is otherwise. The rain that descends in the wet season, collects in all the hollow places, and as the sun's rays cannot get at it through the foliage above, there it remains; these places are called Lagoons. After some time they stagnate, and become foul, from the decomposition of the vegetation that falls into them; but if the next rainy season follows at the time expected, they are replenished with fresh water, and are, in fact, washed out, as the abundance of rain forces their contents to the rivers, and thence to the sea; but should it happen, as it did in the great sickness I allude to, that the rainy season does not follow at all, and the dry weather be

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extended to three times its usual length, then these pools become a thrice concentrated essence of malaria and infection, acquiring a colour almost as black as ink, from the constant rotting of the vegetable matter that falls into them. * * * About the termination of the long period of dry weather I am speaking of, I had occasion, just after the commencement of the heavy rains, to ride about thirty miles along the coast. The several rivers that I crossed were pouring out black and fetid water into the sea, and darkening the colour of the ocean for a considerable distance around their mouths; and the stench was such as to make it exceedingly unpleasant in crossing them, so much so that I was obliged to dash through them, by riding partly into the sea, and then to gallop away from them as from a pestilence. These rivers continued to pour out water of this kind for about a fortnight before their waters resumed the usual colour of the freshes." Here we have the formation of bituminous schists going on on a small scale, and in a way perfectly in accordance with the views of those geologists who advocate the hypothesis, that the vegetable matter forming our beds of coal was drifted from adjoining lands into a neighbouring estuary, as well as others, who suppose that it grew on the places where it is at present found.

It is not my intention in the present Paper to go at length into the respective merits of these hypotheses, the latter of which has been so fully and ably maintained by my friend Mr. Bowman, but merely to allude to them as connected with the remains of the Fossil Fishes at present under notice. In the first case, we must suppose that the inhabitants of the neighbouring waters into which the fetid waters flowed, either did not, or could not escape their poisonous effects. I am not aware that Mr. Hawkshaw noticed the destruction of any fishes in the vicinity above alluded to, but from testimony afforded me by old fisher-

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men on the banks of the Trent and Ouse, I am led to conclude that some fish, especially salmon, very soon desert rivers on the water becoming tainted with decayed vegetable matter. In these rivers, the drainage of the peaty bogs of the Counties of Lincoln and York has caused a great influx of impure water, and induced the fish to desert their former haunts for others in which the waters have not been so contaminated. Indeed, the streams in the neighbourhood of Manchester, according to the evidence of old people, formerly contained both salmon and trout, which have now deserted them, owing to the influx of the impure waters from the numerous dye works and other manufacturing establishments on their banks. Both these instances seem to prove what we should naturally expect, namely, that the fish deserted the water on its becoming foul. It must also be remembered that no remains of fishes have as yet been discovered in the *Four Feet* or the *Cap Coal*, where we have every reason to believe that they would have been preserved as well as in the beds of Cannel.

On the other hand, assuming that the vegetable matter, forming our coals, grew on the places where it is now found, we must admit that it was submerged beneath the adjoining waters by one of those subsidences of the land which the whole coal field proves to have been of frequent occurrence during its formation. From the Carboniferous Limestone to the highest coal measures the remains of numerous *Conchifera* and *Mollusca* clearly shew, that the creatures formerly inhabiting them could not have existed in the great depths of water, under the pressure to which they must have been exposed, had the level of the bottom been permanent, a depth fully equal to one thousand fathoms.

We have always been accustomed to consider our earth the type of solidity, and firmness, and are therefore unwilling to allow of former changes of the level of land and

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water. In addition to the numerous proofs of the rising of land which may be adduced in the old world; the whole continent of South America, (according to the observations of the distinguished naturalist Mr. Charles Darwin,) within, comparatively speaking, a recent geological epoch, has been raised from the bed of the ocean; and that the forces uplifting it have remained quiescent for long periods of time, and then again come into action, as the numerous terraces, through the plains of Patagonia, sufficiently attest.* The same author (at p. 590) shews that Keeling's Island is gradually subsiding; and that a great belt of surface, four thousand miles long and six hundred miles broad, in the South Sea, including the Georgian Archipelago, is sinking (p. 563). Consequently it is not unphilosophical to assume, from the effects we now see being produced, that such subsidences once took place on the surface of our globe during the formation of the coal fields. If, therefore, a large tract of tropical forest, similar to that mentioned by Mr. Hawkshaw, containing lagoons of water, highly charged with bituminous matter, were quickly submerged beneath the level of the surrounding waters, a sudden and rapid rush of them would necessarily take place, carrying all the finny inhabitants into the space formerly dry land clothed with rich and luxuriant vegetation, or covered by poisonous lagoons; and here we should have the fishes involuntarily carried into noxious waters, like those in which the basses were formed, without any chance of saving themselves by flight; many of these would, on death, sink to the bottom, and soon be buried in the black mud deposited from the turbid waters; we should probably also have both fresh water and marine fishes mixed together in one common destruction; and, lastly, we should

* See Narrative of the Surveying Voyages of Her Majesty's ships *Adventure* and *Beagle*, vol. III, p. 204.

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fully account for the absence of the remains in the *coal itself.*

As before stated, the Fossil Fishes in the Lancashire coal field have as yet been discovered only in the beds of cannel, or highly bituminous schists. These deposits are of rare occurrence, and very small amount, when compared with the great thickness of the shales and sandstones, or even coals, which constitute the great mass of the strata. The shales and sandstones all clearly shew that they were deposited by water, just in a similar manner to what we now see taking place in our own seas and lakes. In the waters from which the shales were deposited, like the waters of the present day, lived races of the *Pecten*, *Goniatites*, *Unio*, &c., whose shells, like those of the recent *Anodon*, are preserved, but these shales, as in our recent deposits, are destitute of the remains of fishes; not, probably, because fishes did not exist in the waters, but because their remains have not been preserved. Accordingly it is fair to presume that the destruction and subsequent entombment of fishes in the ancient waters was not in the ordinary course of nature, but effected by some extraordinary convulsions of the earth's surface, which occurred after long periods of repose.

Under all circumstances it appears to me that the subsiding hypothesis for the formation of coal, although not free from objection, will account for the occurrence of the Fossil Fishes in the places where they now are found, better than the drifting and permanent level view of the origin of coal. If I am correct in this view, the area upon which the Lancashire coal field (and probably others) was formed once constituted the mouth of some great river, a delta (resembling that of the Niger, as described in Messrs. Lander's Journal, vol. III. p. 226,) which has been subjected to numerous subsidences, as indicated by the present seams of coal. That the clay now forming the floor of the

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Four Feet coal was once a fertile sedimentary deposit, the *detritus* of some ancient continent, carried down by a tranquil flow of water which silted up the bay, where it was deposited until the *Stigmaria* grew on its rich mud like the mangrove of the present tropical seas in the Brass country; that this and other aquatic plants, the luxuriant growth of years, furnished the mass of vegetable matter now constituting the *Four Feet* seam of coal; then, by one of those subsidences before alluded to, it was submerged to the depth of a few feet beneath water. On its becoming fixed the bed of fire clay was deposited on which these plants again flourished, and yielded vegetable matter sufficient to form the *Cap* coal and stagnant lagoons of poisonous water highly charged with carbonaceous matter. Afterwards, that a rapid subsidence took place to the depth of about forty feet, which caused the waters of the adjoining sea (hurrying on to destruction its finny inhabitants) to rush over the vegetable matter, and entomb the fishes in the beds of fetid mud now forming the impure Cannel, Ironstone, and Bass; that on these last-mentioned strata being thrown down to the bottom, the waters became more pure, and allowed the existence of the molluscous inhabitants of the bivalve shells; then, that in succession the 5 yds. 2 ft. 6 in. of Blue Leys, the 2 ft. 6 in. of Rock, and the 2 ft. 2 in. of Rock Warrant (a fine grained admixture of Silica and Alumina), were formed; and that the last named deposit having reached nearly the surface of the waters, the plants now composing the 6 in. bed of coal grew. Afterwards, that a great submergence to the depth of near two hundred and fourteen feet took place, and all the strata up to the *Yard* coal were successively deposited.

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ART. IX.

On the Economy of raising Water from Coal Mines on the Cornish principle. By Mr. WILLIAM FAIRBAIRN.

Read 29th October, 1840.

NOTHING in modern days connected with the various operations of Mining, is of more importance than the best and most economical mode of clearing the mines of water. In this duty the steam engine performs so important a part, that the progressive improvement of this mighty agent—indispensable to the miner—must be regarded with intense interest. By the geologist its improvements will be looked forward to with additional pleasure, since by its means he will be enabled to explore the earth to a much greater depth, and to follow up his investigations under circumstances more favourable to an accurate examination of the fossil remains of the vegetable and animal kingdoms. During the infancy of Mining pursuits, when the unexhausted stores of mineral wealth lay within the easy reach of man, his operations were not much impeded by a superabundant quantity of water, but in process of time as the sides of the mountains, which rose above the general level of the country, were spoiled of their treasures, it became necessary to penetrate to considerable depths, in order to obtain, not only the necessary supplies, but minerals of greater value. For this purpose every means and appliance were employed, to clear the mines of water and to enable the workman to prosecute his labours—water, wind, and animal power were

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successively brought into operation, but until the introduction of the steam engine, it was a hazardous, and frequently a fruitless attempt to combat with the water at great depths, or to expect a profitable return for the employment of time or the investment of capital.

In almost every district where mineral treasures are found embedded at a great depth in the strata, it becomes necessary to erect, on the surface, large and powerful engines, first to assist in the process of sinking, and afterwards to raise the water and keep dry every part of the mine. In such cases the use of the steam engine is strikingly exemplified; particularly at some of the deep coal mines in the counties of Durham and Northumberland, where the bottom of the shaft is, probably, not less than seven hundred feet below the level of the sea, and where the miner, in sinking, has to contend with innumerable difficulties—sometimes he has to penetrate and work through soft and porous strata, at others, through layers of quick sand of great thickness, and so heavily charged with water, as frequently to baffle the skill of the ablest engineers. On these occasions the aid of the steam engine is constantly required, not only whilst effecting the excavations, but to assist in securing the sides of the shaft, in retaining and supporting the material, and in rendering the whole works perfectly water tight. To sink through beds of this description, where the sands are in a fluid state, is a work of great difficulty and expense, and several thousand pounds are not unfrequently expended in sinking to a depth of a single yard. In some situations the quantity of water is so great as to require a circular casing of solid oak, from ten to twelve inches thick, inserted in segments, with their joints securely wedged, and made perfectly water tight to a depth of several hundred feet. In others, where the miner has to contend with running sand, it has been found necessary to case or surround the whole interior of the shaft with segments of cast iron, firmly

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united with bolts, and forming a large cylinder of sixty to one hundred feet in depth. In these and similar cases, the most powerful hydraulic machines are in constant demand, and without their assistance the most useful and most valuable portions of the mineral kingdom would remain in their hidden recesses, and be lost to mankind.

Amongst geologists it is well known that the internal parts of the earth, as far as they have yet been investigated, do not consist of the same uniform stratification, but of various substances imbedded in laminæ extremely different from each other as regards either their specific gravity, appearance, or chemical proportions. In those beds are found innumerable cracks and fissures, which form drains for carrying off the superfluous water from the earth's surface, and for rendering it fit for the support of vegetable and animal life, they further add to the comforts and enjoyments of man, by retaining for his use one of the greatest luxuries in life, a constant and never failing supply of pure water. To these may be added the renovating and medicinal properties of springs which flow from the different strata of our saline and chalybeate deposits. But the retention of water is not the only benefit which mankind derives from the cracks and fissures in the strata, they are of equal value as the great depositories of mineral treasure, and in these fissures are found the richest and most important of our metallic ores. In Cornwall we have tin and copper, and in Derbyshire, Wales, and Northumberland, the deposits of lead and silver abound. Although we derive our chief supplies of tin, copper, and lead, from these districts, yet it seldom happens that the richest ores are found nearest the surface; they are generally imbedded at great depths, and can only be obtained by the application of steam power.

In some situations the mines are worked by drifts or adits, which enter from some valley in the lower sides of the mountains, and answer the double purpose of draining

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the mine, and extracting the ore. This can, however, be accomplished only in situations where the "lodes" are found in the mountains, and at levels higher than the surrounding valleys. Under these and similar circumstances, a number of mines in Cornwall, Derbyshire, and other parts, are most advantageously wrought, and by carrying the adits at a low level the miners are enabled to extract the ores at a moderate expense. Indeed, miners are so fully aware of these advantages, that they will sometimes spend large sums of money in driving drifts which, occasionally, extend to a distance of two miles from the entrance.

In the introduction of this subject I have been induced to notice the foregoing facts, in order to illustrate more clearly the use and importance of hydraulic machines, and to enumerate the more prominent cases where their assistance is indispensable. From what has been stated, it is evident, that the products of our mines, whether consisting of coal, copper, lead, or other ores, cannot be extracted, without first clearing them of water. The quantity of water varies according to circumstances, but it has always been, and must continue to be, a desideratum in the working of mines, to effect the discharge at the least possible expense, and to adopt those improvements which have been effected with so much skill in Cornwall. It is for these objects, and from a conviction of the inferiority and great inefficiency of the hydraulic machines used in the north of England, when compared with those employed in the southern counties, that I am desirous of drawing the attention of coal proprietors, generally, to the following facts, confirmatory of the great perfection and important saving effected by the Cornish system of draining.

Mr. Taylor, in his Records of Mining, states "that the history of mining in this country is intimately connected with that of the steam engine, and if we had time to examine both we should find that as the mines were the scenes

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of the early inventions or improvements of this machine, so they have not only benefited by it, and in a great measure become dependant upon it, but have gone on contributing to the latest period towards its perfection and economy." In this opinion I perfectly concur; the greatest improvements in our pumping engines have originated and been progressively perfected by persons immediately connected with the Cornish mines. The quantity of water to be raised, and the high price of coals in these districts, operated as a powerful stimulus to improvement, and called forth a system of economy in the use of fuel, for which the Cornish engineers are so deservedly commended. The practice of publishing the monthly reports did more, however, for the improvement of the steam engine and economy of fuel, than any other circumstance connected with the history of that important machine.

The system of recording the performance of the engines, was first resorted to in the years 1811 and 1812, and from that time to the present the most beneficial effects have been the result.

Doubts have been entertained as to the accuracy of measuring the duty* of the Cornish engines, but I am per-

* A late president of the Royal Society, Davies Gilbert, Esq., on his definition of the term duty, says "that the criterion of the efficiency of ordinary machines is the force multiplied by the space through which it acts, the effect which they produce, measured in the same way, has been denominated duty; a term first introduced by Mr. Watt in ascertaining the comparative merit of steam engines, when he assumed one pound raised one foot high, for what has been called in other countries, the dynamic unit, and by this criterion one bushel of coal has been found to perform a duty of thirty, forty, and fifty millions augmenting with improvements, chiefly in the fire-place, which produce a more rapid combustion, with consequently increased temperature and more complete absorption of the generated heat, in addition to expansive working, and to the use of steam raised considerably above the atmospherical pressure."—*See Lean's Report.*

There appears to be some confusion amongst engineers and practical men relative to the term duty. In Cornwall it is understood to be the weight of water raised by a given quantity of fuel; in other districts it is considered

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suaded there is no foundation for such an opinion, as the number of millions of pounds lifted one foot high by a bushel of coals (which is the criterion of the duty) is determined in two ways, first, by calculations founded on the length of the stroke and the bore of the pump; and secondly, by correct measurements of the absolute quantity of water discharged.

Mr. Taylor, one of the first authorities on the subject of Cornish mining, observes, "that in order to satisfy the doubts and remove the misapprehensions which exist as to the impartiality and care with which the accounts are taken, that they are done at the expense and under the directions of those who of all others it most concerns, to see that a correct estimate of the merits of each engine is produced, meaning, the proprietors of the mines, whose interests are inseparable from the economical employment of those machines, and who look"—as Mr. Taylor justly observes—"to these accounts to govern them in the choice of engines, and in their judgment of those who erect and superintend them." There cannot, therefore, exist a doubt respecting the accuracy of these returns, as the number of experiments made to determine the amount of work done, and the quantity of fuel consumed in a given performance, are in themselves sufficient to establish the facts that the Cornish

as the load raised or resistance overcome. Now there is a wide difference between the duty performed and the effect produced; the one being an entirely commercial question, indicating a certain performance at a given rate, whilst the other signifies the whole power expended and the quantity of fuel consumed. In the Cornish engines, of the same construction, and by the same makers, there is a great difference in the duty; one engine for instance may be nicely balanced in the pit with good pumps, valves, rods, &c., and another may labour under many defects as respects the pit machinery, and consequently have a much greater weight to overcome. These two cases are, therefore, very dissimilar, and although the steam engines may be equally perfect as regards the power exerted, yet the quantity of water raised will be much greater in the one case than the other. The term duty is, therefore, not commensurate with the effect; the effect being entirely independent of friction and other expenditure of power.

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pumping engines accomplish a much higher duty than has yet been obtained in this or any other country. Amongst the first experimenters and engineers to whom we are indebted for these advantages may be classed the names of Smeaton, Watt, Grose, Lean, and Woolf, and more recently, Henwood, Wicksteed, and Parkes, have largely contributed to the advancement of our knowledge in that department of practical science.

From the days of Savery and Newcomen, in 1707, to those of Beighton, in 1717, the steam engine received but few additions. It remained stationary till the year 1769, when Smeaton first commenced upon his improvements. At that period the average duty of fifteen atmospheric engines amounted to five millions five hundred and ninety thousand pounds, lifted one foot high by a bushel of coals.* These improvements continued, and the duty, in 1772, was raised to nine millions four hundred and fifty thousand pounds.

Mr. Watt's improvements commenced in 1776, when the average duty was declared at twenty-one millions six hundred thousand pounds, more than double that of Smeaton's; and, during the years 1778-9, it was still further increased.

In 1779, and from that to 1788, Mr. Watt introduced the improvement of working steam expansively, which raised the duty to twenty-six millions six hundred thousand pounds. From 1788 to 1812, few, if any, improvements were made in the Cornish engines; and, provided we except the plunger pole, which was introduced about this time, I question whether the Cornish engineers and miners did not

* A bushel of coals weighs ninety-four pounds, and is used in Cornwall as a measure for determining the number of millions of pounds of water lifted one foot high, the time of lifting not being considered. Mr. Watt was the first to adopt this method for ascertaining the comparative merits of steam engines.

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retrograde rather than advance during a period of twenty-four years.

In 1814, considerable advances were made, which raised the duty to thirty-two million pounds. During that year, Woolf's engine with two cylinders was introduced, which again advanced the duty to fifty-four million pounds.

Mr. Woolf, above all others, did most for the Cornish engines, by showing the advantages peculiar to high pressure steam, and prepared for subsequent improvements, which led to the present effective system of expansive working.

During a period of six years, from 1814 to 1820, Woolf's double cylinder engine maintained its superiority, and gave a higher duty than any other.

Woolf's engine, in process of time, gave way to others of a better construction. They were introduced by Captain Samuel Grose, whose experiments upon the generation and preservation of heat led to great improvements, and ultimately established a new era in the history of the Cornish engine.

In 1826, Captain Grose's engine, at Wheal Hope, attained a duty of sixty-two million pounds; and, in July of the following year, one of Mr. Woolf's single cylinder engines performed the then unprecedented duty of sixty-seven millions.

From that time Captain Grose's improvements were appreciated, and generally introduced; they led to a still greater advance in the duty, which, in 1827, reached as high as eighty-seven million pounds.

Messrs. Lean and Brothers report the duty of a few of the Cornish engines, at this time, as follow:

	Millions.
Wheal Towan Engine.....	87.0 lbs.
Wheal Hope.....	74.8 ,,
Consols.....	67.6 ,,

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	Millions.
Binner Downs	63.5 lbs.
Consols	61.7 „
Consols	61.3 „
Wheal Vor	61.1 „
Wheal Towan (Druce's)	59.4 „
Consols	58.4 „
Poldice	57.8 „
Wheal Vor	51.9 „

These give a mean duty of sixty-four millions of pounds.

Nothing remarkable took place till 1834, when the duty was raised to ninety million pounds; since then it has continued to increase in the ratio of ninety, one hundred, and one hundred and ten millions; and, during the last meeting of the British Association at Glasgow, Mr. Taylor reported the present duty at the unequalled performance of one hundred and twenty-three millions, three hundred thousand, five hundred and ninety-three.

Having briefly stated the progressive improvements that have taken place in the Cornish system of pumping, I would now direct attention to the important results which these improvements have produced.

Previously to entering upon this part of my subject, it may be necessary first to describe the engine, and subsequently to illustrate, by drawings and diagrams, the process by which these improvements were effected.

The Cornish engine, as now constructed, is what is technically called, *single-acting;* that is, the force of the steam is applied on one side of the piston only, and that during the time of lifting the load. On the out stroke, or during the descent of the plungers and pump rods, the steam (after it has performed the lift) is admitted from the upper to the lower side of the piston, and the pressure being equal, the return stroke is effected by the preponderance of the weight in the pit. This system of working is of all others the

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most effective yet introduced, it is based upon the principle of applying an efficient and preponderating force to a mass of matter in a state of rest, to give it motion, and to maintain that motion for a limited period of time. On this principle—accompanied with a proper distribution of the forces as applied to the load—hinges (in my opinion) the whole merit of the Cornish system.

If we minutely examine the process by which these performances are effected, it will be found that the Cornish engineers have very judiciously availed themselves of every advantage which the result of many trials and forty years' experience have produced. At an early period they adopted the principle of working their engines expansively, they increased the pressure of the steam on the piston, and regulated its application with a degree of skill, which gave extraordinary (and what have been considered by some) doubtful results. They were, however, conclusive, so far as regards the reports, and are borne out by facts which are generally admitted to be correct. A reference to the drawings will, however, better explain these statements, and probably remove erroneous impressions respecting this improved system of working, first introduced by the Cornish, and now practised by most other engineers.

Suppose the steam engine, as represented in the drawing, plate II. fig. 1,* to have terminated the return stroke, every thing at rest, and the piston in that quiescent state ready to commence the lift. In such a position, a rush of high pressure (or, as Mr. Parkes calls it, percussion) steam is suddenly introduced, the inertia of the load in the pit is overcome, and motion ensues. This motion would, however, soon terminate but for the expansive action which takes place when the communication between the cylinder and the boiler (now open) is suddenly cut off. This is done at a

* For explanation of figure, see description of plates.

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very early period of the piston's motion, by rapidly closing the steam valve, and thus excluding the further admission of steam, and retaining only a small volume (probably not more than one-sixth of the contents of the cylinder) to urge forward the piston and terminate the stroke.

At first sight this force would scarcely appear adequate to the immense load which has to be raised; but on further examination we shall find the process and likewise the contrivances for these objects equally ingenious and effective. Having overcome the vis inertiæ of the mass, it will be found that the remainder of the stroke is duly effected by the steam's expansive action, and the consequent enlargement of its volume to the end of the stroke.

At the termination of the stroke, the equilibrium valve which connects the upper with the lower side of the cylinder opens, and the steam—now greatly attenuated—is admitted from the upper to the lower side of the piston, and the pressure being equal on both sides, the return stroke is performed in equilibrio by the weight of the pump rods as they descend in the pit.

When the retrograde motion takes place, it will be observed that the steam in the cylinder having expanded in volume to five or six times its bulk is greatly reduced in pressure, and the force being no longer equal to the resistance, the return stroke must of necessity take place as soon as the equilibrium valve effects the communication between the top and bottom of the cylinder.

From this, it is clear that the return stroke will be made with a velocity due to the weight in the pit; and from its accelerated motion, might be attended with danger, if it were not counteracted by the equilibrium valve, which shuts before the termination of the stroke, and retains a portion of steam between the piston and the cylinder cover. This steam is forcibly compressed as the piston ascends, and

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operates as an elastic cushion to receive the shock against the cylinder cover.

Mr. Parkes, in his Treatise on the Action of Steam in the Cornish Single-Pumping Engine, gives numerous examples relative to the methods adopted for regulating the Cornish engine. He states "that the steam at its entrance into the cylinder exceeds in pressure that of the force opposed to it, or the engine would not stir; at the termination of the stroke, the pressure is reduced below that of the resistance, and that the sum of the forces operating throughout the stroke, must be sufficient to carry the piston to the end of its course, or it would not arrive there."

He farther goes on to state, that "the mass of matter set in motion by the steam's initial force on the piston, acts the part of a fly wheel. "It first absorbs the excess of power over the resistance, and then faithfully discharges it, by assisting to continue the engine's motion during the steam's expansion, and consequent diminishing force below the pressure of the resistance. But this mass of matter possesses no power-creating virtue; it merely husbands at one period of the stroke, and restores it at another, that force which was given to it; it exerts no power of its own."

In further elucidation of this subject, it may be useful to direct attention to the annexed indicator diagrams (see plate II. *a*), taken from the Hoskins' and Davey engines by Mr. Enys, in 1837. In the previous year my engineer, Mr. Robert Smith, took several indicator figures of the engines in Cornwall, which on comparison with those since taken by Mr. Henwood, Mr. Enys, and others, are very similar in their appearance and character.

The indicator is an instrument of great vulue for ascertaining the performance, and pressure upon the piston of every description of engine. It has long been used as a

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test of the performance of rotative engines, and has more recently been applied with equal success to the high pressure single-acting engine. The annexed diagrams exhibit the correct pressure of the steam upon the piston of three distinct engines, at every point of the stroke. The first was received from Professor Mosley of King's College, London, and those taken from the Davey and Hoskins' engines, were handed to me by Mr. Enys. They are correct copies of the originals.

Diagram I. was taken from one of the Cornish engines, and exhibits an accurate transcript of the action of the engine from the commencement to the termination of the stroke. It exhibits high expansive action, which, it will be observed, takes place when the piston has descended only twelve inches. It gives the extreme elasticity of the steam when it enters the cylinder, its continued pressure to a point corresponding with 1-11th of the stroke, and its varied expansive action until the piston has completed the whole distance from A to B, eleven feet. In this diagram, the pressure of the steam acting upon the piston at every division of twelve inches of the stroke, will be nearly as follows:

Eleven feet stroke.

Distance in feet.		Pressure in lbs.
1	.....	38.0
2	.....	23.5
3	.....	18.0
4	.....	14.8
5	.....	12.3
6	..... CYLINDER	10.5
7	.....	9.4
8	.....	8.6
9	.....	7.8
10	.....	7.8
11	.....	7.0

Mean pressure, 14.33 lbs.

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The maximum pressure per square inch upon the piston is therefore 38 lbs., and the minimum, or state of the steam's elastic force at the end of the stroke, is 7 lbs., giving a mean of 14.33 lbs. throughout the stroke.

Diagram II., from Davey's engine (Consolidated mines), exhibits a different figure to that just described. It would appear from the diagram that the steam valve is continued longer open, and the steam's expansion does not commence until the piston has made twenty-seven inches of the stroke; after attaining this point, expansion begins, and the lines described in both cases by the instrument are nearly alike. The steam's elastic pressure in the Davey engine is not so great at the commencement of the stroke as in the first diagram, but it is longer continued, and the momentum consequently increased before expansion takes place.

The forces acting upon the piston in this engine, during the working stroke, are in divisions of twelve inches,* equal to a mean pressure of 17.4 lbs. on the square inch.

Eleven feet four inches stroke.

Distance in feet.	Pressure in lbs.
1	32.7
2	32.7
3	24.4
4	20.5
5	16.5
6 ..... CYLINDER	14.0
7	12.0
8	11.3
9	10.0
10	9.1
11.33	8.2

Mean pressure, 17.4 lbs.

* The length of the stroke in the Davey engine is eleven feet four inches, but the figure is divided in the usual manner at equal distances of twelve inches, which causes an enlargement of the lower space equal to sixteen inches of the depth of the cylinder. This difference in dividing the stroke

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In the Davey engine the steam is not so much attenuated at the close of the stroke as that indicated by diagram No. I.; probably this may be accounted for by a difference in the load, the resistance to be overcome being in the latter case 13.12 lbs. per square inch. I have no records of the duty performed by the engine as represented in No. I. diagram, but No. II. and No. III. give respectively, seventy million twenty-six thousand, and sixty-seven million three hundred thousand pounds raised one foot high by a bushel of coals.

Diagram No. III. is taken from the Hoskins' engine, and is nearly similar to that which represents the Davey engine. At the close of the steam valve from the point *a*, down to the atmospheric line *b*, there is a flickering motion in the instrument, which indicates a variable pressure, arising probably from a jerking motion in the pumps, as the load ascends. In other respects the figures are similar in appearance, and the load on the piston nearly the same.

Some months ago I was in correspondence with Mr. Enys on the subject of the indicator as applied to single acting engines on the Cornish principle, and, from the constant and frequent opportunities that gentleman has for recording facts, I entertain hopes that the public will shortly be in possession of numerous data relative to this important and all absorbing subject.

has no effect upon the pressure, which on a careful examination would be nearly the same at the termination, eleven feet four inches, as it was at eleven feet.

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ART. X.

Notice of Upper Silurian Rocks *in the Vale of Llangollen, North Wales; and of a contiguous eruption of Trap and Compact Felspar. By* J. E. Bowman, F.L.S. & F.G.S.

Read 25th February, 1841.

In the course of an investigation undertaken during the last summer at the suggestion of Mr. Murchison, to endeavour to ascertain more precisely the boundary between the Silurian and Cambrian systems through Montgomeryshire and Denbighshire, I found that much time and labour and the examination of a more extensive district would be necessary, and that many alterations in the latest geological maps would be necessary. I was soon aware that it would be extremely difficult, if not impossible, to ascertain the line of junction, in consequence chiefly of the numerous dislocations that had broken up the whole country, and the superficial covering of diluvium which so generally concealed the beds; and I gradually adopted the opinion, that neither by its lithological structure, nor its fossils, can the Upper Cambrian group be distinguished from the Lower Silurian. But it is not my intention to enter upon this difficult subject till my present views shall be confirmed or modified by future observations on a wider scale; the only object of the present Paper being to make known one or two very interesting features which I unexpectedly came in contact with in the course of my investigations, and which are not noticed upon the best and latest geological maps.

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The accompanying sections have been constructed on the uniform scale; that is, they shew the heights and horizontal distances in their natural and true proportions. This would not have been practicable before the publication of the beautiful maps of the Ordnance Survey, nor without the altitudes of the mountains liberally communicated at my request by Colonel Colby. I have adopted Mr. Murchison's colouring throughout; though in subdividing into three, that portion of the Upper Silurian which in the localities whence he has drawn his type is confined to a single character, it became necessary to invent some distinction. This subdivision I have endeavoured to make intelligible by differences in the engraving, and the reference at the conclusion of the Paper.

The schistose rocks which compose the lofty ridges to the north and south of the valley of the Dee between Corwen and Llangollen, and the scarcely less rugged intermediate country through which that celebrated river circuitously flows, have been referred to different members of the great Slate formation of North Wales. The chain that hems in this mountain tract to the north commences near Corwen, and running north-east comprises the bold hills of Moel Morfidd, Gribin Oirnant, and Moel y faen, which contain many extensive and celebrated slate quarries. The long ridge to the south is called Cefn uchaf; it stretches eastward as far as the meridian of Chirk, and divides the valleys of the Ceiriog and the Dee. In the former, its base contains many seams of a true fissile slate, and others with a less perfect cleavage, which are worked in many quarries both for roof slate and large flags, and pass under the general name of the Glyn slates. Both of the above chains may be considered as bifurcations or spurs of the great Berwyn range, which here gradually subsides to the eastward, and finally disappears under the Denbighshire coal field.

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The Upper Silurian rocks of the Vale of Llangollen may be therefore arranged, as follows, in the descending series.

Upper Silurian of Murchison.

Upper Division.

1. Compact thin grey micaceous beds, composed of siliceous, argillaceous, and calcareous particles, bearing a general resemblance to similar beds at Ludlow, &c., though very scantily supplied with fossils. Hill of Castell Dinas Bran, Llangollen fechan.

Equivalent. Upper Ludlow. Murch.

2. Blue unfossiliferous shale. Foot of Castell Dinas Bran.

Equivalent. Lower Ludlow? Murch.

Lower Division.

1. Thin beds of hardened more siliceous schist. Both sides the Dee above Llangollen.
2. Parallel beds of light blue grey shale, streaked and banded. Wriddiog; upper part of Cefn uchaf.
3. Slates and flags, generally dark and glossy with large Orthoceratites, Cardiola interrupta, and Graptolithus Ludensis. Glyn and Oirnant quarries.

Equivalent. Wenlock shale. Murch.

It so happened that I commenced my examination of these rocks from the south, where none of their true relations can be seen; and I spent much time and many laborious traverses in different directions, before I could obtain any direct evidence of their true geological position. The slates and flags they contain are so unlike the rock of the same age in Shropshire, Herefordshire, and Montgomeryshire, that but for such evidence, or that of organic remains (which very rarely occur) they would not be recognised as the equivalent of the "Mudstones" of those

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districts; or, in other words, as the lower member of the Upper Silurian formation.

On ascending the hill of Castell Dinas Bran, which rises above the north bank of the Dee at Llangollen, and abuts against the great limestone escarpment of the Eglwyseg, I found it to be of *Upper Ludlow* rock, bearing its usual character of a compact micaceous thin bedded shale; and was delighted to discover in it well defined specimens of Terebratula Navicula, two or three species of Cypricardia, and other usual fossils of that formation. Mr. Murchison says that Terebratula Navicula is confined to the *lower* portion of the Upper Ludlow, and to the subjacent Aymestry limestone. It was in searching for this limestone, that I found, at the foot of the south spur of Castell Dinas Bran, (which has been cut through to form a passage for the feeder of the Ellesmere canal) a blue shaly rock, very different from the Upper Ludlow on close comparison, being thicker bedded, scarcely micaceous, and altogether unfossiliferous. It was in contact with, and rose up conformably from underneath the latter, the dip of both being six to eight south-east, or toward the valley of the Dee; but there was no appearance of any intervening limestone, or tendency to a calcareous character in the beds either above or below the junction. I afterwards found the same shale, with a general uniformity of dip, in several places on the opposite or south bank of the Dee, to the east of Llangollen, in the cuttings of the great Holyhead road. At Llangollen-fechan, one mile and a half to the east, the Upper Ludlow may be seen lying upon this shale, which rises from beneath, and forms the higher part of the hill behind. I considered, therefore, that notwithstanding the absence of the dividing limestone, this blue unfossiliferous shale might be the equivalent of the *Lower Ludlow*. It is not of great thickness, but soon passes downwards into a harder and apparently more siliceous schist, which I have placed at the top of the lower

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division of the Upper Silurian. These beds are streaked with thin parallel bands of a lighter and darker blue, and are altogether barren of fossils. They are of very considerable thickness, since they form the bed of the Dee for more than a mile above Llangollen bridge, the conical heights of Y Voel Abbey, 750 feet high on the north, and extend up to the quarry of Bachau, and the top of Craig y Gadd, on the south bank, which last is 1050 feet above the Dee at Llangollen; and as the dip varies from six to twenty-six, their thickness may be estimated at about 800 feet. I may briefly mention, that these hardened strata in the bed of the Dee are very rugged and broken, with a constant dip of six or eight in the direction of the current, so that while their smooth surfaces give great rapidity to the stream, their projecting edges are constantly obstructing it. These opposite causes give to its dark and foaming waters those contrasts of colour, and alternate reaches of turbulence and repose, which form the most interesting features of this justly celebrated river. These banded and hardened rocks, with some modification, also compose the hills for nearly two miles west from Llangollen, and imperceptibly pass downwards into a schist of the same general structure, but of a paler blue with beds of more uniform thickness. On the steep west face of the Wriddiog, by the side of the Holyhead road, the change of character is completed, and the paler beds may be seen largely developed, banded and streaked with others of a whitish cast, quite parallel, occasionally wavy, and sometimes shewing a tendency to a concretionary arrangement. Similar rocks, without any change of appearance, and scarcely of dip (generally six to eight south-east) stretch out to the north in the bold promontory of Rhysgog, and occupy the rugged tract already alluded to, on the opposite bank of the Dee. They are thrown into a perpendicular position on the crusty barren hill of Craig ddu, and on the crest of the Pass of Bwlch y groes that leads

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over the range of slate rocks into the valley of Bryneglwys, clearly shewing that mighty forces must have been necessary to effect such great convulsions. Yet in no part of this tract could I discover the least trace of igneous action.* The same banded rocks also compose the entire height of the great north spurs of Cefn uchaf, east of Moel Ferna, which, from the top of their bold precipices to their bases on the road half way between Llangollen and Corwen, comprise a thickness of not less than fifteen hundred feet. On these hills, and especially on the west slope of the nameless hill (1583 feet high) along which a new road to Nantyr has lately been formed, the schist is repeatedly interstratified with thin beds of hard light coloured greywacke, through which the cleavage planes do not pass. It is probable that the same formation extends to the summit of Moel Ferna (2050 feet high), but the universal breastwork of diluvium that envelopes it, only allows a scanty bit of rock to appear on its cap. This is a kind of dull greywacke, in which I could find no trace of bedding, though I took it to be one of the harder beds interstratified with the softer schists. Here, however, the evidence is as yet very defective; but putting Moel Ferna out of the question, an attentive traverse of these great spurs of Cefn uchaf affords ample evidence, in their structure, colours, uniformity of dip and of bedding (which, south of the Dee, is nearly horizontal), that they are all harmonious portions of one great formation, during whose deposition (however vast the period we may feel compelled to admit it must have required to form them) no material change could have taken place in the nature of the sediment, or in the circumstances

* On the south-east slope of Castell Dinas Bran is a projecting mass of compact greenish felspar, ten or twelve feet diameter, and another of very similar texture, on the north side of Cefn uchaf, on the descent from Bwlch y Clawdd to the great Holyhead road. These are the only spots in the vale of Llangollen where I have seen igneous rocks *in situ*.

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under which it was accumulated; and also that they have gradually passed upwards into those darker banded more siliceous schists, and these again into the thick bedded blue shale which I traced rising up from underneath the true Upper Ludlow rock of Castell Dinas Bran. The changes are everywhere so slight that they can only be considered as modifications of the same deposit; and so gradual that it would be unadvisable, if not impossible, to separate the whole geologically. Yet, looking up towards them from various points below, and to the enormous gullies that sever them, and with the impression of their toilsome ascent fresh in the recollection, and considering also that they compose the immediate flanks, if not the eastern portion of the ridge of the Berwyn itself, it requires a bold and powerful effort of the mind, to separate them from the great Cambrian formation. It may be noticed also that, during the several days I was engaged in their examination, I could not see a single fossil in any part of these banded rocks, though in the Flag quarry at the top of Craig Dduallt, a few miles to the eastward, which undoubtedly belongs to them, I found, in addition to the usual Orthoceratites, Graptolithus Ludensis, a characteristic fossil of the lower part of the Upper Silurian formation.

I have still to mention the third and lowest portion of the group, and that which in an economic and commercial point of view, is the most important, because it contains most of the slate and flag quarries in the district, and is largely worked in both the ranges of hills already described. I shall have no difficulty in connecting these slates and flags upwards with the banded schists last described, or downwards into the true Lower Silurian rocks, from the direct evidence of superposition; or in shewing by a few, but important organic remains, that they belong to the Upper Silurian rocks. First, as to the order of superposition on Cefn uchaf, south of the Dee. If we stand on this

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ridge, about midway between Moel Ferna and the Carn, and face the north, we see below us two deep lateral valleys divided by a lofty hill which rises to the height of 1583 feet, though it is not distinguished by any particular name. At the head of each of these lateral valleys, and under the very ridge of Cefn uchaf, is a quarry, in which blue thick bedded hard flags, often of great dimensions, are procured. That to the east is called Bwlch y Clawdd, and that to the west Briwnant quarry. A regular gradation downwards from the streaked and greywacke beds already named, into the Briwnant quarry, may be traced, first from the summit of the nameless hill to the new road to Nantyr that runs under its western slope, and then along the zigzag declivity that leads down to it, the same dip being uninterrupted throughout, thus very satisfactorily shewing the inferior geological position of the flags. The neighbouring quarry of Bwlch y Clawdd, notwithstanding a slight difference of dip, evidently contains the same description of flags, though probably they are higher in the series, and both are interlaminated with thin greywacke bands. On the opposite or south side the mountain, a satisfactory passage downwards from the middle streaked beds to the slates, may be seen by following the course of a little rill that falls into the Ceiriog, from Chwarel issaf to the Bronith quarry. Again, in the chain of hills on the north of the Dee, where flags and slates of similar appearance and quality are procured, their inferior position to the streaked beds is apparent. And in a subsequent examination of the long hill of Cyrn y Brain, which is a Lower Silurian rock and in the same line of strike, I had the satisfaction to see the lowest beds of these slates distinctly reposing upon the fossiliferous Lower Silurian rock which rose up from beneath them. This was on its south-west flank, just above the road between Ruthin and Llangollen, about one mile south of Davern Dywarch.

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The particulars of dip and cleavage I shall here, as in previous instances, pass over, not wishing to encumber the present brief communication with uninteresting details.

Then as to the evidence of organic remains. In many of the quarries of Cefn uchaf, where the beds and cleavage planes are coincident, as at Bwlch y Clawdd, Garth, Brongillt, &c., large Orthoceratites may frequently be seen on the surface of the flags, sometimes twelve or fourteen inches long and one and a half to two inches diameter at their widest end. In a newly opened quarry called Maes Goran, under Moel y Gamelin, in the chain north of the Dee, I found the same large Orthoceratites, and well defined specimens of Cardiola interrupta, characteristic of, and usually confined to the Lower Ludlow rock.

Briefly to recapitulate.—The lower division I have been describing may be conveniently arranged under three principal groups. First, thin parallel beds of hardened streaked schist, destitute of fossils. The second or middle group, an immense thickness of uniform, parallel beds of light blue shale, some of which, on weathering, assume a whitish colour, giving the section a streaked or banded character. The lower portion is interstratified with hard sonorous greywacke beds, and gradually passes into the third or lowest division, which contains the slates and flags so extensively worked in numerous quarries on Cefn uchaf on the south, and in the hills on the north side of the Dee, as Gribin Oirnant, Moel y faen, &c.

I wish it were in my power to estimate correctly the thickness of these respective groups; but without having sufficient data to enable me to do this, and without going into details that would be tedious, I may venture to state that I consider the upper and the lower group to be each about eight hundred feet, and the middle group of banded schists about one thousand five hundred feet, making a total thickness of about three thousand one hundred feet

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from the base of the Upper Ludlow to the surface of the Lower Silurian. It is of more importance to ascertain their true geological position, and I trust I have satisfactorily shewn them to be the lower members of the Upper Silurian. It would be an extremely difficult and useless task to attempt to identify them more closely either with the Lower Ludlow or the Wenlock shale. Of their two most important fossils, one, the Graptolithus Ludensis, has been found in both; and though the other, the Cardiola interrupta, is not recorded to have been seen below the Lower Ludlow, I have a specimen collected by myself from the lowest bed of the Wenlock shale, in the river Onny, below Horderley. The upper and middle groups are generally very barren of fossils; so that in the absence of the dividing limestones, all we can be certain of is that they lie beneath the Upper Ludlow of Castell Dinas Bran, and upon the Lower Silurian of Cyrn y Brain. No one will now contend that uniformity of lithological structure is necessary to establish geological contemporiety, more especially against the important evidence of organic remains.

As, however, these rocks here assume a character very different from their ordinary type, it may not be amiss to compare the two together, and to endeavour to connect them by others of an intermediate character. Without going far from the district we have been examining, we may see a few miles to the eastward, at the foot of Pont Fadog, on the south bank of the Ceiriog, a *brown soft* shaly rock, which no one acquainted with the usual appearance of the Lower Ludlow, would hesitate to recognize as such; while at Gwern towr, within a mile, and on the eastern extremity of Cefn uchaf, the rock that occupies the same geological position, is blue, hard, sonorous when struck, and does not become brown or rotten by exposure. Many modifications might be men-

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tioned in neighbouring quarries, to show that at least one cause of the change has been its proximity to subterranean heat. There seems, indeed, to be a progressive increase of hardness and durability, as the quarries lie more to the westward, or approach the seat of igneous action; though after a sufficiently long exposure, they all betray, more or less, the prevailing tendency of their prototypes in Shropshire and Montgomeryshire, to go brown and rotten, and become real "*Mudstones*." This is also the case with the altered and rhomboidal Lower Ludlow rock of the Long Mountain and the Railth, near Welsh Pool; and with the still more indurated shales west of Welsh Pool and Llanfair, (of all which I was often reminded in these traverses), and which, though generally destitute of fossils, occasionally contain Orthoceratites and Graptolites, and are recognized as the lower members of the Upper Silurian rocks. They may therefore be considered as intermediate links which connect the soft mudstones of Shropshire with the fissile slates and flags of Denbighshire. The above fossils also occur in the black coarse flags of Nant Glyn and Cyffylliog, on the high table land between the vales of the Conway and Clwyd, which are also probably of contemporaneous formation.

In addition to the above coincidences may be named, the general parallelism, uniformity, and low angle of dip of the beds, which prevail in all the districts that have been named, and which are strongly contrasted with the high angles and great contortions of the true Cambrian slates. Also the occasional tendency to concretions both in beds and in detached ballstones, and the general similarity in structure of the joints and cleavage planes. The distinctness and clearness which these divisions, especially the cleavage, exhibit in the rocks I have been describing, though in some degree they may be due to the nature of the deposit, must be more largely attributed to the intensity of the forces that have crystalized or polarized the particles, and are supposed to

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have been in the greatest activity during the earliest geological periods. The clearness and precision of these divisional planes in some of the quarries I visited (Brongillt) prove that after the deposition of these younger Silurian rocks, these forces were still sufficiently powerful to produce a cleavage, little if at all inferior to that impressed upon the oldest Cambrian slates.

The other new feature I shall now describe, is an elevated plateau of igneous rocks, occupying an area of about twenty square miles, under the east flank of the Berwyn, and between the villages of Llanarmon Dyffryn Ceiriog, and Llansaintfraid Glyn Ceiriog. It is divided by a deep picturesque gorge, through which the infant Ceiriog runs, accompanied by the road between the two villages just named; and is intersected again nearly at right angles by another gorge, so that it is broken up into four irregular quarters, the most elevated parts being the general centre. Having skirted and intersected this plateau in various directions, I can state that the sedimentary rocks have been thrown off from it on all sides; the Cambrian slates from the south and west, Silurian rocks from the north, and Mountain Limestone and Millstone Grit from the east flank. These several rocks occupy more or less of the slopes and gullies; the boundary lines between them and the trap being generally pointed out by the greater fertility of the surface over the sedimentary deposits, and by the sterility of the high felspar district. The central and eastern portions of the plateau, with its flanks and watercourses, and the adjacent country to some distance, are strewed over with scattered blocks of pure white compact felspar, which becomes porous and honeycombed by long exposure. Some of these are equal to the best French burrs, which they much resemble; mixed with them are others of a greenish grey tough sonorous rock, which in

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hand specimens might be called greywacke, but which is easily recognised as of igneous origin, and in many blocks of which, felspar is the prevailing ingredient. Some of these are amorphous, others stratified and of various tints, the colour depending on the proportion of felspar, and varying from nearly white to a dark greenish grey. Immense detached blocks of this trap, both amorphous and stratified, strew the slopes of the central gorges, while others, *in situ*, project in gigantic masses from the rifted precipices, and give to the scene something of a chaotic character. This is especially the case about the intersection of the two gorges at Pandy Melin Deirw, just above which, on the highest point of Pen y Graig, is a column of compact white felspar, twenty to twenty-five yards high, hemmed in on each side by a rude wall of Lower Silurian rock, which it has forcibly rifted in its efforts to escape, and overspread laterally, crowning the precipice as with the splintered battlements of some ruined castle. The width of this column or funnel of felspar is about sixteen or eighteen yards, but on the top, where it has overflowed, it is much greater. The mass is rudely divided, by perpendicular joints, into angular prisms, but these have no definite or symmetrical form. The schist in contact is paler and more splintery than the rest, and in places is almost as white as the felspar itself; but on both sides the funnel, it preserves the usual dip of the whole hill to the north. On the ascent from the bottom of the gorge, it may be seen projecting in various places, and even in the thin partition between the intruded rock and the face of the precipice. The walls of the trap itself, on the sides of the gorge, are rifted and jagged, as though the mass had been torn asunder after it had been consolidated; and these combined appearances seem to show, that after the first ejection, the whole elevated surface has been broken up by a second uplift from below. This latter convulsion may not have occurred till after the deposition of the Millstone Grit; for

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on the eastern flank, near Gwernedd Gymmal, the bastard lime and Millstone Grit are tilted off its side, and dip from the plateau. The trap, also, in many places, when fresh broken, shews in the section a waved or banded appearance, some of the seams being of a paler colour, and nearly pure felspar, especially near the funnel; while its average colour seems to deepen as it approaches the confines, owing probably to the felspar being mixed up with a larger proportion of extraneous matter. These appearances, taken in conjunction with the stratification or bedding of other portions of the trap, seem to indicate that the igneous action was going on simultaneously with the deposition of sedimentary matter, some of the beds partaking of the character of both. On the north-west side especially, the schists are repeatedly interstratified with thin bedded, very hard, greenish traps, which have so uniform a thickness through large areas, and surfaces as smooth as the schists themselves, that they must have been formed by some such process. Some of these bedded traps are micaceous, and are impressed with Lower Silurian Fossils. Some very thick slabs, quarried for building, had both surfaces as parallel as any bedded rock; yet not the slightest difference in the texture or colour was perceptible, on comparing them with the amorphous blocks. Mr. Murchison shows that some of the volcanic grits on the flanks of the Corndon, and elsewhere, must have had a similar origin.

Another independent outburst of igneous matter occurs on the south-west side of the plateau, where the elongated ridge of Mynydd bach (one mile north-west from Llanarmon Dyffryn Ceiriog) is composed of the amorphous trap. The schist has been thrown off, and dips from the ridge on the north and south slopes; is hardened and altered in colour, and its cleavage planes are nearly obliterated. The boundary between it and the trap is clearly marked by a thick vein of pure white quartz, which encircles the summit like a

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rude wall, or is strewed about in great splintered blocks. It marks the site of an ancient camp, which is shewn on the ordnance map, but of which I could not learn that any historical record exists.

The south-east side of the plateau is also studded by a group of detached hills of bedded trap, of a dark colour and coarse fracture. Some of these are of great height, as Foel Rhiwlas, and Moel y Gwelltyn, shewn in the section, and have evidently burst through the slate rocks, which rest upon their sides, and occupy the intermediate hollows. To a similar cause must be attributed some serpentine and crystalline limestone, found under the escarpment of Craig Ysgwennant. (See section.) Other trap rocks occur far to the south-east of Llansilin, and are marked on Mr. Murchison's map.

As the Lower Silurian and Cambrian rocks are intimately connected with this igneous district, and occupy a large portion of the section, I may be allowed to advert shortly to the difficulties that attend their examination, and to point out a few peculiarities they exhibit in the country under review.

Before I commenced my survey, Mr. Murchison apprized me that the Silurian rocks would be found to stretch farther to the westward, or nearer to the ridge of the Berwyn, than they appear to do in his map, which only aimed to give a general outline. In every instance I have proved the correctness of this view; and have collected beautiful and characteristic Lower Silurian fossils from several localities laid down as Cambrian. But in general, no definite boundary could be detected; in Montgomeryshire, where the beds can be traced downwards, the transition is gradual, and more to be pointed out by the absence of organic remains, than by any change in the lithological structure of the rocks. It is very rarely, indeed, that the order of superposition can be observed; 1st, on ac-

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count of the great convulsions which have dislocated and broken up the strata; 2nd, from the great uniformity of the beds through vast thicknesses; 3rd, from the variety of changes which many of them have undergone from igneous action; 4th, from the extent to which the original bedding has been obliterated by the cleavage planes; 5th, from the general absence of organic remains; and lastly, from the almost universal covering of diluvium which has filled up the fissures of dislocation, and concealed the relative position of contiguous strata. These and other difficulties perplex and seriously retard the progress of the geologist, and make it imperative to devote much time and repeated observation, in order to understand the necessary details, and comprehend the true structure of the country. Nor are these difficulties confined to the oldest rocks. We have seen that even the Upper Silurians in Denbighshire are so much disguised from their usual type, that the geologist who has only studied them in the districts so well illustrated by Mr. Murchison, would find himself completely at fault, and would only be convinced of their identity, after having patiently worked out their relations, aided, perhaps, by a solitary fossil, which, after days of close search, he might be fortunate enough to find.

I omitted no opportunity of collecting, as largely as I could, the organic remains of the Lower Silurians, and of the Bala limestones, in the hope, that by comparing them with others from similar deposits in our own and other countries, and also with the Devonian fossils, some progress might be made in defining the limits of these respective formations, and of extending our knowledge of the earliest forms of organic life. I have found, both in the Lower Silurians and in the beds associated with the Bala limes, some molluscs and coralloids, which I have little doubt will prove to be new—at all events, that are not figured in the splendid work of Mr. Murchison; but I am only aware of

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one of these (a bivalve) that is confined exclusively to the latter. If, therefore, there be any boundary between the Upper Cambrian and the Lower Silurian systems, it must be defined by other evidence than that of fossils.

In conclusion, I will only point out one or two peculiarities in the arrangement of the rocks in the section. In addition to the absence of the usual dividing limestones of the Upper Silurian group, already adverted to, the Old Red Sandstone is entirely wanting in the district I have been describing, indeed throughout the whole of Montgomeryshire and Denbighshire; the carboniferous limestone usually resting upon the Upper Silurian. At the north end of Cyrn y Brain, the Upper Silurian is also wanting, and the lime is in contact with the Lower Silurian. But in less than a mile to the north of this point, the limestone also has disappeared, and the Millstone Grit of Moel Grugog rests immediately upon the Lower Silurian.

In the Lower Silurian hill of Mynydd Fron Frys, immediately to the north of the trap plateau, and overlooking the glen of the Ceiriog, are two independent groups of interstratified limestones; the upper accompanied by many courses of flags more or less calcareous, the lower by thick concretionary beds. These limestones resemble those in the hills above Bala in their hardness, and dark blue grey, highly crystalline appearance, and like them produce a brown impure lime, which has the property of setting under water, thus forming another analogy between the Lower Silurian and Upper Cambrian systems. These limestones, and the schist of which the whole hill is composed, contain some good fossils and corals, which, when examined by one familiar with these tribes, will probably be found to be new. The north-west top of this hill contains courses of blue siliceous rock, in which fossils are imbedded, the most abundant being a coral, the Turbinolopsis bina of the Caradoc Sandstone.

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REFERENCE TO THE SECTIONS. PLATE VI.

a. Carboniferous Limestone.

b. Upper Ludlow.

c. Upper division } Lower Member of Upper Silurian.

d. Middle ditto } Lower Member of Upper Silurian.

e. Lower ditto } Lower Member of Upper Silurian.

b. *c.* *d.* *e.* } Upper Silurian.

f. Lower Silurian.

g. Cambrian Rocks.

h. Igneous ditto.

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ART. XI.

Description of some New Species of Fossil Shells, found chiefly in the Vale of Todmorden, Yorkshire. By CAPTAIN THOMAS BROWN, M.R.P.S., M.W.S., M.P.S., Curator of the Manchester Natural History Society's Museum, &c. &c. &c.

I AM indebted to my friend Mr. Samuel Gibson, of Hebden Bridge, Vale of Todmorden, Yorkshire, for the loan of the new and interesting shells from which the following descriptive catalogue and my drawings were made. Almost the whole of the species were discovered by him, as well as many others, in different departments, which enriched the work of Mr. Phillips, on the Geology of Yorkshire.

Situated in a country village, remote from men of science and books, and destined to earn his bread by a laborious employment, this intelligent and excellent individual, has, by his personal energies, apprehension, and great industry, overcome all the difficulties which beset him; and has done more in the way of collecting new subjects in almost every department of local Natural History, than has been accomplished by those who have trodden the paths of natural science under more favourable circumstances. His example has given a stimulus, to the study of nature in the districts around him, and he ever takes delight in initiating all who seek his aid, into the best means of pursuing the investigation of natural objects.

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CLASS I.—MOLLUSCA.

ORDER II.—CEPHALOPODA.

FAMILY AMMONACEA.

Genus GONIATITES.—*Von Buch.*

1. Goniatites undulatus. Plate VII. Fig. 1, 2, 3, 4, 5. Gibson's MSS., No. 6.

Shell subglobose, glabrous, and shining; crossed by numerous, transverse, irregular, undulating, continuous raised lines, which bend downwards as they pass over the ambit; also provided with deep, straight, transverse constrictions; ambit rounded; umbilicus very small, deep, and angulated; aperture wide and expansive.

In the very young state this species is destitute of the transverse lines and constrictions; the umbilicus is large, and exhibits the volutions. Diameter nine lines, thickness a third less.

This beautiful species occurs in fragments at Lambert's Clough, near Todmorden, and at Crosshills, near Skipton, Yorkshire. The distinct and bold undulating lines distinguish this from all its congeners.

In the cabinets of Mr. S. Gibson, Hebden Bridge, and Mr. William Sutcliffe of Heptonstall.

2. Goniatites intermedius. Plate VII. Fig. 6, 7, 8. Gibson's MSS., No. 8.

Shell discoidal, subcompressed; crossed by indistinct, wide-set, continuous, doubly bent undulations, which dip rapidly in an arcuated manner as they pass over the subcarinated ambit, which is a little compressed; constrictions regular, broad, shallow, and greatly arcuated on the sides, and in passing over the ambit; volutions three, and rapidly increasing; umbilicus large and deep, with raised, angular edges, and exhibiting the three volutions. Septa, the dorsal lobse single, sole-shaped, with a truncated point; a single, pointed lateral sinus, and two rounded lateral lobes;

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aperture wide and deep. Greatest diameter two inches, thickness nine lines.

This rare Goniatite is found at High-Green Wood, near Hebden Bridge, and is in the cabinet of Mr. Gibson.

3. GONIATITES SUBSULCATUS. Plate VII. Fig. 9, 10. Longthorn's MSS., No. 13.

Subrotund; ambit broad, subdepressed, with a deep sulcus in its centre; constrictions wide, nearly equidistant, rather deep, plain, rounded, narrow below them on the surface, smooth, and arcuated as they pass over the ambit; surface covered with transverse, strong, bifurcate, gently bending striæ, which emanate from the umbilicus, where they are strong, the bifurcations terminating on the margin of the dorsal sulcus; umbilicus rounded, rather wide; aperture semilunar and rather small; dorsal lobe short, the whole lateral lobes rounded. Diameter five lines, thickness three lines.

Found in nodules of Limestone Shale, in the neighbourhood of Hebden Bridge. Rare. In the cabinet of Mr. Gibson.

4. GONIATITES DORSALIS. Plate VII. Fig. 11, 12, 13. Gibson's MSS., No. 14.

Discoidal, subcompressed; ambit somewhat flattened, and subcarinated in the centre; aperture longer than wide; whole shell covered by numerous, fine, acute, transverse striæ, thick as they emanate from the umbilicus, and become bifurcate as they diverge outwards, and are abruptly arcuated as they pass over the side towards the ambit; these are crossed by rather wide-set, spiral, and nearly obsolete striæ, constrictions irregular, shallow, and striated, and considerably arcuated as they approach the ambit; septa with two rounded lateral lobes; one pointed lateral sinus, and a simple, rounded, central dorsal lobe. Diameter seven lines, thickness about one line and a half.

Found in nodules of Limestone Shale, at High-Green

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Wood, Vale of Todmorden. In the cabinet of Mr. Gibson.

5. Goniatites jugosus. Plate VII. Fig. 14, 15. Gibson's MSS., No. 15.

Discoidal; with five gradually enlarging volutions, crossed by numerous, elevated, sharp, strong, oblique ribs, which emanate from the umbilicus, and become bifurcate, or trifurcate, gradually thickening as they approach the ambit, terminating in a gentle curve on the margin of the broad, smooth, dorsal sulcus, with which the slightly rounded ambit is invested; the sides of the shell rise abruptly, and have a carinated aspect; constrictions irregular, shallow, and partaking of the same curvature as the ribs; aperture compressed and semilunar; umbilicus very small and shallow; dorsal lobe of the septa narrow, truncate, with parallel sides, lateral lobes and sinuses rounded. Diameter three lines, thickness one line and a half.

This species has somewhat the aspect of *G. Gibsoni*, but differs in the dorsal groove being smooth, and in the form of the septa.

A rare species, found in the Limestone Shales in the neighbourhood of Hebden Bridge. In the cabinet of Mr. Gibson.

6. Goniatites splendidus. Plate VII. Fig. 16, 17, 18. Gibson's MSS., No. 17.

Discoidal, smooth, glossy; interior volutions enveloped in the outer one; umbilicus minute; ambit subacute; aperture large, wide, oblong-ovate; surface covered with sigmoidal striæ; septa numerous, the dorsal lobe long and truncate, with the sides parallel; dorsal sinuses trifid, with the first lobe very long, and rounded; second acute; third short, and obtusely angular; lateral sinuses very wide, divided into two parts by a very deep acute lobe, the first part bifid, the second rounded. Diameter nearly half an inch, thickness a quarter. The young form is unknown.

Only one specimen of this beautiful species has been

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found, at High-Green Wood, near Hebden Bridge, and is in the cabinet of Mr. Gibson.

7. GONIATITES KENYONI. Plate VII. Fig. 19, 20. Gibson's MSS., No. 20.

Somewhat ovate, compressed, smooth, the outer volution enveloping the others; ambit rounded, with a thin, sharp carina along its centre; umbilicus small, shallow; surface covered with very minute, spiral striæ, which can only be detected by the aid of a strong lens; septa numerous, with rounded lobes and sinuses; lateral sinus wide, double; dorsal sinus simple. Diameter two lines and a half, thickness a third less.

This species differs from *G. Looneyi* in its dorsal sinus being simple; and from *G. Gilbertsoni* in having double lateral sinuses, and in the dorsal sinus being simple; and from both in being spirally striated.

Found in the Limestone Shales, near Hebden Bridge. In the cabinet of Mr. Gibson.

8. GONIATITES PARADOXICUS. Plate VII. Fig. 21, 22. Gibson's MSS., No. 21.

Elliptical, subdepressed, smooth, shining; aperture subrotund; umbilicus of moderate size, shallow, the sides gradually rising from it; ambit subcompressed, gently rounded; surface covered with very minute, spiral striæ; septa with rounded lobes and sinuses; the dorsal sinus double, lateral sinus simple. Diameter two lines, thickness a line and a half.

Distinguished from the *G. Kenyoni* by the form of its septa; and from the *G. Gilbertsoni* in being spirally striated.

A very rare Goniatite, only one specimen having been hitherto found in the Shale at the bottom of High-Green Wood, Vale of Todmorden, and is in the cabinet of Mr. Gibson.

9. GONIATITES LONGTHORNI. Plate VII. Fig. 23, 24, 25, 26. Gibson's MSS., No. 21.

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Elliptical, subcompressed; with three rapidly increasing volutions; aperture ovate; umbilicus small; sides covered with numerous, doubly arcuated, flat, indistinct ribs; septa with all the lobes and sinuses rounded and equal. Diameter twelve lines, thickness half its diameter.

In the young condition it is smooth with directly transverse constrictions.

Found sparingly in the soft Shale near Hebden Bridge. In the cabinet of Mr. Gibson.

10. Goniatites Proteus. Plate VII. Fig. 27, 28. Gibson's MSS., No. 23.

Discoidal, compressed, lenticular; volutions numerous; umbilicus deep, funnel-shaped, exhibiting the margins of the volutions, the external margins of which are enveloped in the outer one; margin of umbilicus with an elevated ridge; ambit produced, slightly flattened in the centre, sides spirally striated, and crossed by numerous, nearly obsolete, lines of growth; constrictions indistinct; aperture oblong-ovate, equal to a third of the diameter of the shell; septa with all the lobes and sinuses rounded. Diameter seven lines, thickness two lines and a fourth.

In the young condition it is considerably compressed, and the constrictions are distinct, broad, and deep; these fill up as the shell advances in growth.

This shell may be distinguished from *G. Spirorbis* (Brown, Fossil Conch., p. 30, pl. 21, fig. 45, 46) in the umbilicus being smaller, and angular, and in its being spirally striated, in the aperture being much more elongated, in the ambit being more produced, and in the indentations from the volutions being more acute, and following the form of the septa.

Found at Lob Mill, near Todmorden, by Mr. John Haworth, and is very rare. In Mr. Gibson's cabinet.

11. Goniatites parvus. Plate VII. Fig. 32, 33. Gibson's MSS., No. 35.

Spheroidal, with straight constrictions; umbilicus large;

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surface covered with exceedingly minute, transverse striæ; aperture semilunar; septa with all the undulations low and rounded; dorsal sinuses very wide. Diameter three-fourths of a line, thickness about the same.

Found at Hoolebottom, near Todmorden, and is in the cabinet of Mr. Gibson.

12. GONIATITES MINUTISSIMUS. Plate VII. Fig. 29, 30, 31. Gibson's MSS., No. 26.

Discoidal, subglobose, smooth; with three rounded volutions, the inner ones only half concealed; aperture semilunar; umbilicus large, moderately deep; septa unknown. Diameter one-third of a line.

This rare and handsome Goniatite is the smallest known species. It was found among the remains of some unknown fossil plants, at Millwood, near Todmorden, and is in the cabinet of Mr. Gibson.

13. GONIATITES SMITHII. Plate VII. Fig. 34, 35. Gibson's MSS., No. 27.

Discoidal, subglobose, very thick; sides narrow; ambit very broad, slightly produced in the centre; umbilicus very large, funnel-shaped, and deep, exposing the margins of the inner volutions, and with an acute margin; aperture semilunar; constrictions directly transverse; the whole surface covered with strong, regular, transverse, slightly waved striæ; aperture semilunar, narrow; septa, dorsal lobe simple and rounded, dorsal sinus rounded and very small; first and second lateral lobes angular, with their edges parallel; lateral sinus rounded. Diameter eight lines, thickness about six lines and a half.

This species differs from *G. Listeri* in the form of the septa.

This rare Goniatite is found associated with the *G. Proteus* at Millwood, near Todmorden.

Named by Mr. Gibson in honor of his friend Mr. Smith of Bury, Lancashire.

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It may be interesting to the local geologist to know that the following already described Goniatites are to be met with in the Vale of Todmorden.

13. G. LISTERI. Coal Shales, near Todmorden.

14. G. MUTABILES. Coal Shales, near Todmorden.

15. G. CALYX. Coal Shales, near Todmorden.

16. G. VESICA. Limestone Shales, near Todmorden.

17. G. STRIOLATUS. Calcareous Nodules, near Todmorden.

18. G. RETICULATUS. Limestone Shales, near Hebden Bridge.

19. G. EXCAVATUS. High-Green Wood, and at the Summit Tunnel.

20. G. STENOLOBUS. High-Green Wood.

21. G. PAUCILOBUS. Limestone Shales, near Hebden Bridge.

22. G. MICRONOTUS. Limestone Shales, near Hebden Bridge.

23. G. GIBSONI. Limestone Shales, near Hebden Bridge.

24. G. LOONEYI. Calcareous Nodules, High-Green Wood.

25. G. DISCREPANS. High-Green Wood.

26. G. SERPENTINUS. Hoolebottom, near Todmorden.

FAMILY ORTHOCERATA.

GENUS ORTHOCERA.—*Lamarck.*

1. ORTHOCERA OBTUSA. Plate VII. Fig. 36. Gibson's MSS.

Shell erect, taper, slightly compressed; surface smooth, covered with undulating, transverse striæ; the point for a quarter of an inch destitute of striæ, next which the striæ are very fine and close-set, gradually widening as they ascend, and becoming more undulous. Diameter near the

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base three-quarters of an inch, greatest known diameter an inch and an eighth.

Found at High-Green Wood, near Hebden Bridge, in the Vale of Todmorden, by Mr. Gibson, and is in his cabinet.

2. ORTHOCERA MICROSCOPICA. Plate VII. Fig. 37, 38. Gibson's MSS.

Shell taper, smooth; with the septa remote; aperture semioval. Length a line, thickness not the fourth of a line.

Found at High-Green Wood, Vale of Todmorden. In the cabinet of Mr. Gibson.

3. ORTHOCERA ASCICULARIS. Plate VII. Fig. 39. Gibson's MSS.

Shell very long, and tapering rather abruptly; smooth; septa numerous, transversely parallel, regular, and increasing with age; aperture circular; sephuncle near to one side. Length almost an inch and an eighth, diameter at aperture not an eighth of an inch, and a third of an eighth at the base.

Found in the soft Shale at Todmorden, and is in the cabinet of Mr. Gibson.

4. ORTHOCERA BROWNII. Plate VII. Fig. 40. Gibson's MSS.

Shell subulate, arcuated; with seven longitudinal, elevated ribs; giving the shell a septangular form; general surface smooth; septa numerous, undulating, more remote as they ascend. Length one inch and a quarter, diameter one-sixth.

Found at Todmorden, and in the cabinet of Mr. Gibson; by whom it was named after the author.

GENUS BELEMNITES.—*Lamarck.*

1. BELEMNITES GIBSONI. Plate VII. Fig. 41.

Shell tapering gradually, smooth, and shining; aperture

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nearly circular. Length five-eighths of an inch, diameter at aperture an eighth of an inch.

Found at Crimsworth Dean, in the Limestone Shale, and is in the cabinet of Mr. Gibson.

Named in honor of Mr. Gibson.

ORDER TRACHELIPODA.

FAMILY PURPURIFERA.

GENUS BUCCINUM.—*Lamarck.*

1. BUCCINUM MANNI. Plate VII. Fig. 53, 54.

Shell oblong-ovate; body and spire of equal length; the latter furnished with four gradually tapering volutions, not very deeply divided, terminating in an acute apex; aperture with a short central canal at its base. Length two-tenths of an inch, diameter half its length.

Found at High-Green Wood.

Named in honor of Robert Mann, Esq., surgeon, Manchester.

2. BUCCINUM GIBSONI. Plate VII. Fig. 48, 49.

Shell ovate, smooth; body large; spire very small, consisting of three rapidly diminishing volutions, terminating in an acute apex; aperture oblong-ovate, a little contracted both above and below; outer lip sharp, even; pillar lip slightly reflected on the columella. Length half an inch, diameter about three-quarters of an inch.

Found at High-Green Wood, near Todmorden, and is in the cabinet of Mr. Gibson.

3. BUCCINUM ELEGANS. Plate VII. Fig. 50, 51.

Shell oblong-ovate, smooth, glossy; body large, ventricose; spire of medium length, consisting of four gradually, rapidly diminishing, but not deeply divided, volutions, terminating in an acute apex; aperture oblong-ovate, contracted above and rounded below; outer lip sharp, and

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even. Length a quarter of an inch, diameter one-eighth of an inch.

Found at High-Green Wood, near Todmorden, and is in the cabinet of Mr. Gibson.

4. BUCCINUM FLEMINGII. Plate VII. Fig. 52.

Shell oblong-ovate, smooth, glossy; body large; spire short, consisting of three well defined and rapidly diminishing volutions. Length three-eighths of an inch, diameter three-sixteenths of an inch.

Found at High-Green Wood, near Todmorden, by Mr. Greenwood, and is in his cabinet.

Named in honor of Dr. William Fleming, of Broughton View, Pendleton.

FAMILY TURBINACEA.

GENUS PYRAMIS.—*Brown.*

Shell generally subulate, gradually tapering to a point; body usually short, and the spire long; volutions but slightly divided by the suture in most species, and seldom inflated; aperture mostly oblong-ovate, placed nearly perpendicular, with its upper angle contracted for the most part; outer lip rarely continuous.

1. PYRAMIS RETICULATUS. Plate VII. Fig. 42, 43.

Shell subulate; body shorter than the spire, which consists of six inflated, rapidly decreasing volutions, well defined by a deep suture, and terminating in an acute apex; aperture slightly ovate, contracted above, and rounded below; pillar lip not reflected on the columella; outer lip thin, plain, and sharp on the margin; whole shell decussated with fine distinct, spiral, and longitudinal striæ. Length five-eighths of an inch, diameter nearly three-eighths.

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Found at Crimsworth Dean, near Hebden Bridge, and is in the cabinet of Mr. Gibson.

2. Pyramis Oweni. Plate VII. Fig. 44, 45.

Shell subulate, smooth; spire long; body short, about a third of the length of the shell; spire consisting of six well defined, moderately inflated, and slightly oblique volutions, terminating in an obtuse apex; aperture subrotund, a little contracted above, rounded beneath; outer lip strong, and even. Length a quarter of an inch, diameter a tenth of an inch.

Found at Crimsworth Dean, near Hebden Bridge, and is in the cabinet of Mr. Gibson.

Named in honor of John Owen, Esq., of Hollybank, one of the Secretaries of the Natural History Society of Manchester.

FAMILY SCALARIA.

Genus CIRRUS.—*Sowerby.*

1. Cirrus Gloveri. Plate VII. Fig. 46, 47.

Shell conoidal, smooth, glossy; body very large, much inflated; spire very small, consisting of three rapidly diminishing, ventricose volutions; aperture round; inner lip slightly reflected on the columella, with a shallow umbilicus behind it; outer lip thin, and even. Length three-eighths of an inch, diameter three-sixteenths of an inch.

Found at High-Green Wood, near Hebden Bridge, by Mr. Gibson, and is in his cabinet.

Named in honor of Thomas Glover, Esq., of Smedley Hill.

ORDER GASTEROPODA.

Genus PILIOPSIS.

1. Pileopsis minutus. Plate VII. Fig. 55, 56, 57.

Shell smooth, glossy, conical, with the vertex slightly

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spiral and inflected; aperture subovate, and expansive. Diameter about a line.

Found at High-Green Wood, near Todmorden, and is in the cabinet of Mr. Gibson.

GENUS PATELLA.

1. PATELLA GREENWOODI. Plate VII. Fig. 58, 59.

Shell subovate, conical, smooth, slightly wrinkled, transversely subdepressed; the vertex inclined anteriorly.

Found in the Limestone Shale, near Hebden Bridge.

Named by Mr. Gibson in honor of Mr. James Greenwood of Todmorden, an industrious collector of fossils.

CLASS CONCHIFERA.

ORDER I.—MONOMYAIRA.

FAMILY BRACHIOPODA.

GENUS SPIRIFER.—*Sowerby.*

1. SPIRIFER GLOVERI. Plate VII. Fig. 60, 61.

Shell nearly circular, very convex; the valves with rounded sides; both valves with a central furrow, which widens as it retires from the umbones, deep in the upper valve, and shallow and more effuse in the under valve; beaks produced, rounded, and rather near; both valves with divergent striæ, crossed by distinct lines of growth; lower margins of valves flexous, the central base of the upper one terminating in a considerably produced beak, and hollow in the opposite valve; hinge line rather short. Length nearly three-quarters of an inch.

This species differs from *S. globularis* in being spirally striated.

Found in the lower scar Limestone Gravel at Sheden Clough, near Cleviger, and is in the cabinet of Mr. Gibson.

2. SPIRIFER FILARIA. Plate VII. Fig. 62, 63.

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Shell nearly orbicular, rather flat; beaks small, pointed, and contiguous, but not inflated; exterior surface covered with five divergent, longitudinal striæ, crossed by numerous lines of growth; inside of valves with five divergent striæ; hinge line very short. Length three-quarters of an inch.

Found near Settle. In the cabinet of Mr. Gibson.

FAMILY MALLEACEA.

GENUS AVICULA.—*Lamarck.*

1. AVICULA OBLIQUA. Plate VII. Fig. 64.

Subdepressed; valves very oblique; hinge line nearly parallel, and long; with numerous, elevated, divergent, longitudinal ribs, emanating from the slightly produced umbones, and terminating a little beyond the margins, giving them a fine crenulated appearance, crossed by numerous lines of growth; provided only with small anterior ears, destitute of ribs. Length nearly half an inch, breadth the same.

Found at Crimsworth Dean.

2. AVICULA SAMUELSII. Plate VII. Fig. 65.

Semicircular, wider than long; hinge line parallel, no distinct ears; umbones small, pointed, and but slightly produced beyond the hinge line; whole shell covered with longitudinal, divergent ribs, which emanate from the umbones, and pass to the margins, over which they protrude, and give a fine pectinated appearance; crossed by numerous, distinct lines of growth. Length upwards of a quarter of an inch, breadth a third more.

Found at High-Green Wood.

Named in honor of my respected friend John Samuels, Esq., of Barton House, Manchester.

GENUS CATILLUS.—*Brongniart.*

1. CATILLUS KIRKMANI. Plate VII. Fig. 66.

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Oblong-ovate, convex, smooth; sides nearly equal, marked with four concentric lines of growth; the umbones prominent, central, and rounded, with several inequidistant, concentric lines of growth; margins sharp, and even.

Found at High-Green Wood, Todmorden, and is in the cabinet of Mr. Greenwood of Todmorden.

Named in honor of my friend Thomas Kirkman, Esq., of Springfield-lane, Salford.

2. CATILLUS LÆVIS. Plate VII. Fig. 67.

Shell oblong-ovate, smooth; with numerous concentric, nearly obsolete wrinkles; umbones small, rounded, and but slightly produced. Length nearly three-quarters of an inch, breadth half an inch.

Found at High-Green Wood.

3. CATILLUS COSTATUS. Plate VII. Fig. 68.

Shell oblong-ovate; with numerous, very flat, longitudinal, divergent lines of growth, emanating from the umbones, and one terminating on the margins; these are crossed by numerous, distinct lines of growth. Length half an inch, breadth three-eighths.

Found in the Vale of Todmorden, and is in Mr. Gibson's cabinet.

4. CATILLUS OBLIQUATUS. Plate VII. Fig. 69.

Ovate, smooth; umbones rather large, and placed considérably to one side; surface with several distinct lines of growth; sides unequal, one considerably produced, the other short, and nearly straight.

Found at High-Green Wood, and is in Mr. Gibson's cabinet.

5. CATILLUS MINUTUS. Plate VII. Fig. 71, 72.

Shell modiolaform, much elongated, smooth; with distinct, concentric lines of growth; umbones small, rounded, and placed to one side. Length about one line, breadth two-thirds its length.

6. CATILLUS KELLYII. Plate VII. Fig. 73.

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Shell mytiliform, elongated, smooth; with concentric lines of growth; umbones small, rounded, and considerably turned to one side; valves narrow above, and wide, and rounded towards the base.

Named in honor of my esteemed friend M. J. O'Kelly, Esq., of Rochestown House, County of Dublin, one of the earliest and most zealous promoters of Conchology in Ireland.

Genus GERVILLIA.—*Defrance.*

1. Gervillia minor. Plate VII. Fig. 70.

Shell very oblique; umbones flat, placed much to one side; hinge line long, straight; surface with numerous, concentric, strong, rude wrinkles, with lesser intermediate ones. Length three-eighths of an inch, breadth three-quarters of an inch.

Found at High-Green Wood.

FAMILY MYTILACEA.

Genus MODIOLA.—*Lamarck.*

1. Modiola Moorei. Plate VII. Fig. 74.

Shell transverse, subcuniform, inflated, smooth; base oblique, pointed at one side; beaks small, acute; with many concentric, strong lines of growth, and very fine, intermediate, irregular striæ over the surface, which can only be discovered by the aid of a strong lens; posterior slope extending considerably beyond the umbones. Length an eighth of an inch, breadth somewhat more.

Found at Crimsworth Dean, in the Vale of Todmorden, by Mr. Gibson, and is in his cabinet.

Named in honor of John Moore, Esq., of Old Sale Hall, one of the earliest cultivators of Natural History in Manchester, and one of the founders of the Manchester Natural History Society.

2. Modiola minuta. Plate VII. Fig. 75.

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Shell transversely oblong-ovate, smooth; umbones small, and considerably produced and pointed; anterior side considerably rounded. Length an eighth of an inch, breadth something more.

Found on a Calamite in Shale, at Low Moor, near Bradford.

ORDER II.—DIMYAIRA.

FAMILY CONCHACEA.

GENUS CYTHERÆA.—*Lamarck.*

1. CYTHERÆA ANTIQUA. Plate VII. Fig. 76.

Shell smooth, thick; umbones but little produced, slightly turned to one side. Length and breadth about an eighth of an inch.

Found in the Limestone Shale, Vale of Todmorden.

GENUS ARTEMIS.—*Poli.*

1. ARTEMIS PARVA. Plate VII. Fig. 77.

Shell smooth, nearly orbicular; umbones a little turned to one side; surface with a few distant, distinct lines of growth. Diameter somewhat more than the eighth of an inch.

Found in the Ironstone Shale.

FAMILY NYMPHACEA.

GENUS LUCINA.—*Bruguière.*

1. LUCINA DUBIA. Plate VII. Fig. 78.

Shell nearly orbicular, considerably inflated; umbones large, rounded; surface with many concentric ridges. Diameter an eighth of an inch.

Found at High-Green Wood.

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CLASS ANNELIDES.

ORDER SEDENTARIÆ.

Genus VERMILIA.—*Lamarck.*

1. Vermilia minuta. Plate VII. Fig. 79.

Shell smooth, generally semilunar; aperture subtriangular, gradually tapering to a sharp point. Exceedingly minute, and can only be seen by the aid of a strong lens.

Found in the Shale adhering to a specimen of *Pecten dubius*, and is in the cabinet of Mr. Gibson.

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Note, by Mr. Fairbairn, *to Article IX.*

The observations in the Paper read before the Manchester Geological Society on the 29th of October, 1840, were confined to the improvements which have taken place in the construction of the various parts of the Steam *Engine*, and the principle on which the peculiarity of the Cornish system of pumping depends.

It must not be imagined, however, that the whole merit of the process rests exclusively with the engine. The management of the Boilers, and the arrangement of the Pit-work, are matters requiring equal consideration and attention.

In the Pit-work, it is absolutely necessary to have the lifting pumps and plungers arranged, and the preponderance of the descending weight in the pit adjusted, so as to effect the return stroke at as nearly as possible a maximum velocity. Judging from my own experience, and that of the best Cornish engineers, I should consider that the in-door, or working stroke, should move at a rate of 250 feet, and the out-door, or return stroke, at about 140 feet per minute. Peculiar circumstances, arising probably from the number of strokes to be performed and the quantity of water to be raised, occasion considerable variations in the speed; but the general opinion appears to be in favour of nine strokes per minute, and the above velocity is probably the nearest approach to a maximum duty.

In the Boilers, the principle of construction, the capacity, flues, furnaces, &c., require the strictest attention. Slow

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combustion and abundance of boiler space are important desiderata—equally essential to the economical management of the common condensing engine, as to the Cornish principle of expansive working.

These points properly attended to, combined with the best description of clothing, would tend greatly to reduce the consumption of fuel, and consequently effect considerable saving in the working of our mines.

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PLATES III. and IV. Views of Fossil Trees at Dixon Fold, Nos. 2 and 5 (see pages 115 and 117), referred to in Art. VI. Observations on the same Fossils; by Mr. BOWMAN. p. 212.

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PLATE VIII. Illustrating Art. IX. On Raising Water from Mines; by Mr. FAIRBAIRN. , p. 179.

Fig. 1 is taken from the drawings of a pumping engine made in the year 1839-40, for Messrs. Biolley et Fils, of Verviers, in Belgium.

The cylinder A is 70 inches diameter with double working beams B, bolted together, each 30 feet long, 5 feet 10 inches deep in the centre, and constructed upon Mr. Eaton Hodgkinson's principle of the strongest section. The top and bottom ribs are parabolas, and from their form are calculated to sustain great pressure, and to resist the shocks of impact to which engines of this description are subject.

The stroke in the cylinder and pit is 10 feet, and the air pump E (35 inches diameter) is worked from the outer end of the large beam at C. Both the air pump E and condenser F are placed near to the shaft, having a long eduction pipe G, and supplied with water from the adit by the pumps D. The steam and eduction valves are upon the equilibrium principle; they are worked by the plug rod S, and regulated by the cataract in the usual manner.

Figs. 2, 3, and 4 represent the pit-work, and sectional views of the pumps and plungers. Fig. 2 shews the position of the pump rods H and plunger pump I below the adit, or point of discharge. Fig. 3 is a sectional view of the lower plunger pump and valves, with the rod M descending to the lifting pump N (fig. 4) which terminates in the well at the bottom of the pit. K is the plunger pole, in its descent forcing through the valve L into the barrel communicating with the upper lift, the water previously raised by the lifting pump N. The whole depth of the pit is 720 feet, and the pumps are divided into three lifts as follows:

First. A double set of bucket pumps, each 120 feet long (one set being kept in reserve), to lift from the bottom of the pit to the first cistern.

Second. A set of plunger pumps 180 feet long, forcing the water from the first to the second cistern; and lastly, another set of plunger pumps of the same length (180 feet) forcing the water from the second cistern to the point of discharge, through an adit 240 feet below the top of the shaft. From the adit, a portion of the water is raised by two sets of plunger pumps, each 120 feet long (D fig. 1), to supply the condenser.

PLATE IX. Indicator diagrams referred to in pp. 190, 191.

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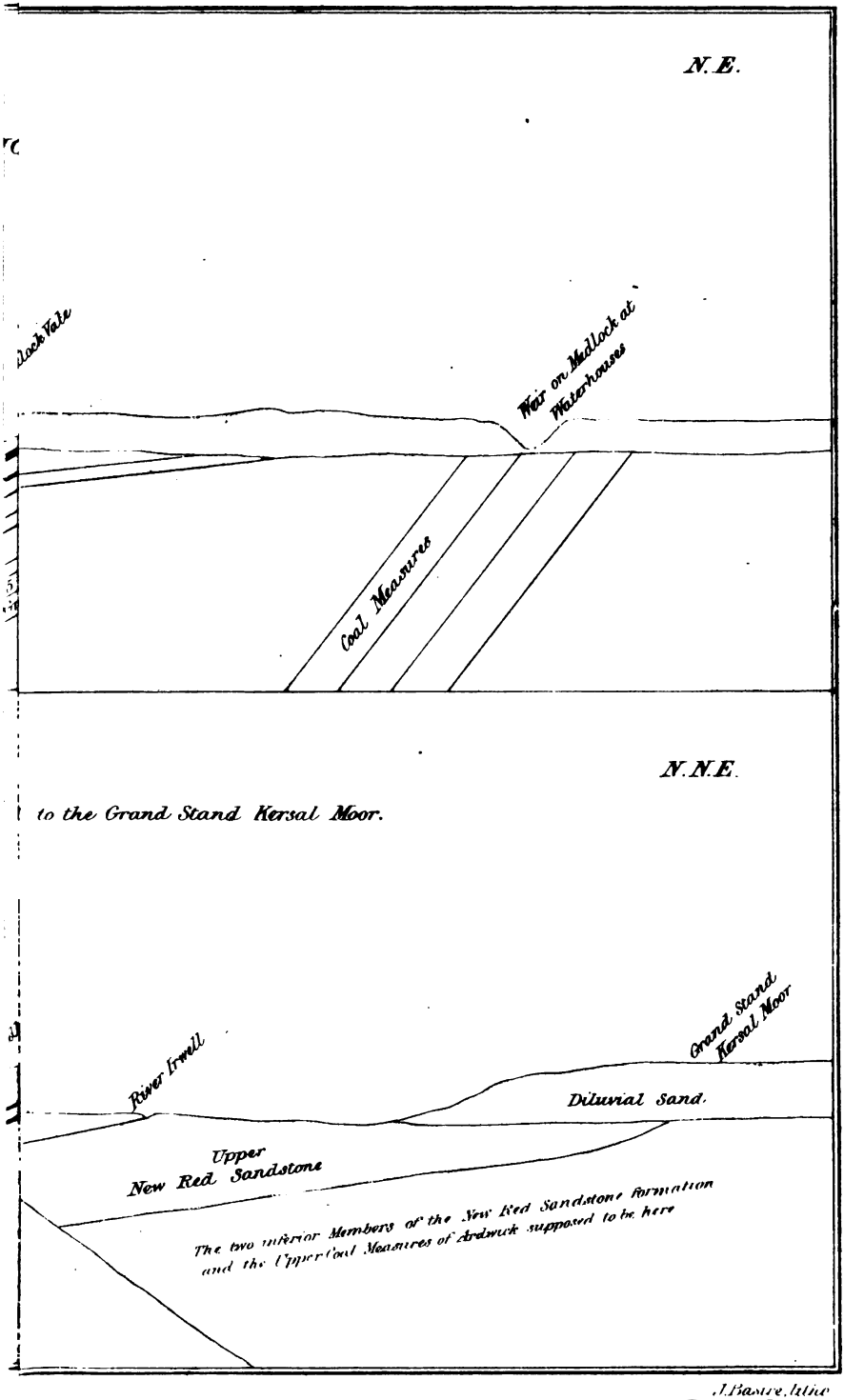

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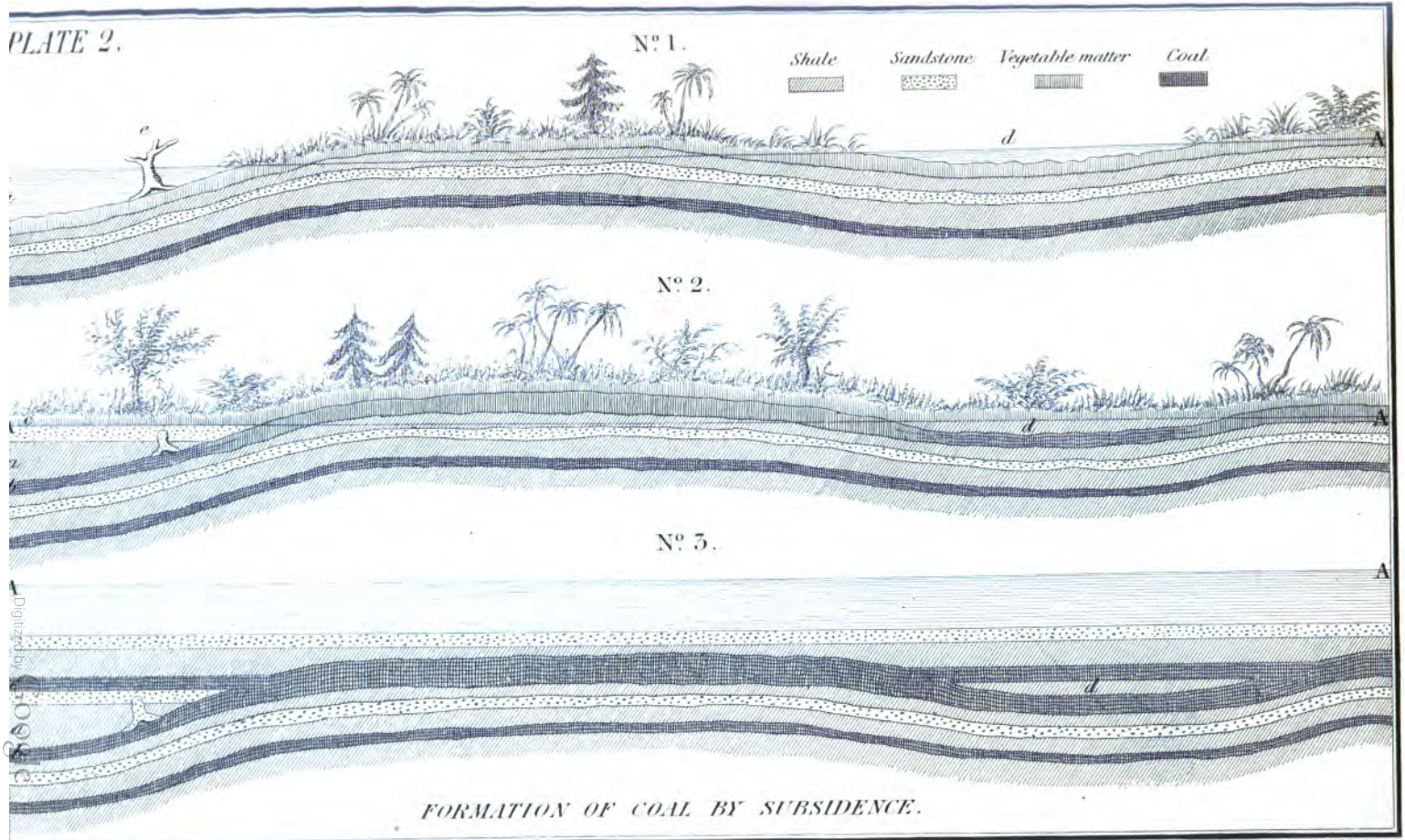
PLATE 2.



FORMATION OF COAL BY SUBSIDENCE.

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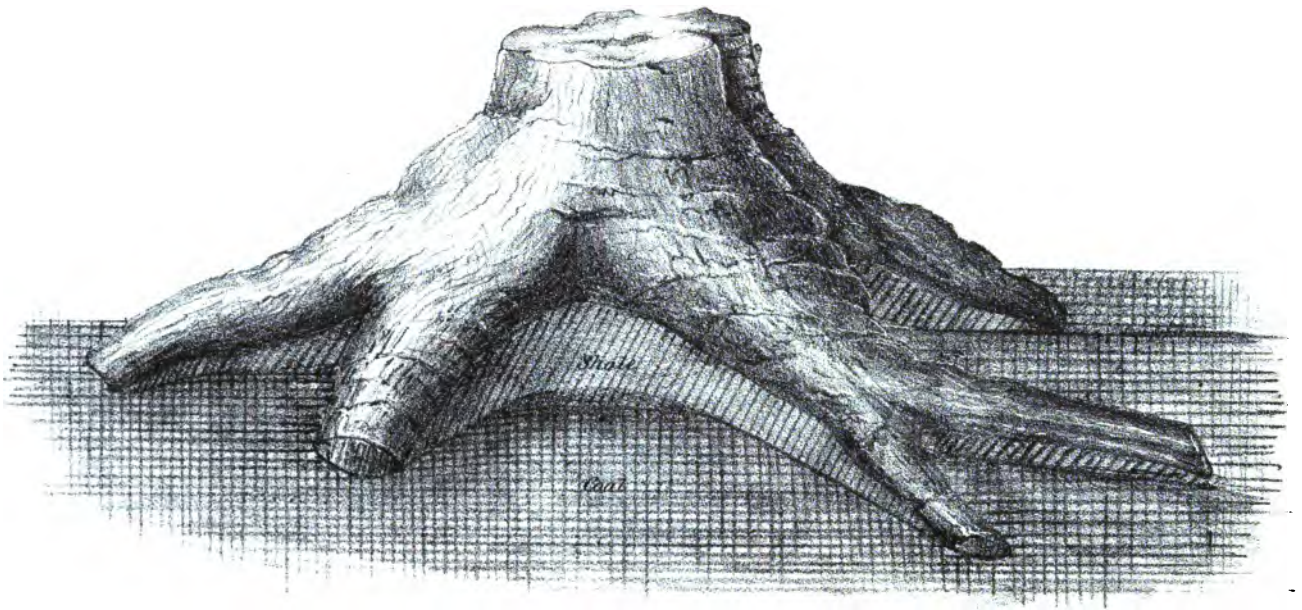
Plate 3.



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Fossil Tree, N° 2. Scale ½ inch to 1 Foot.

J. Basire, lith.

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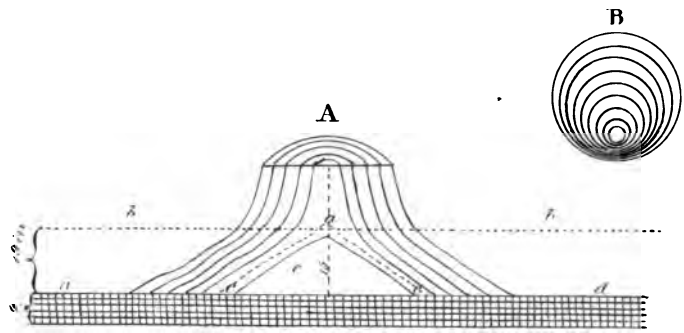
Plate 4.

Fossil Tree, No. 5. Scale ¼ in. to 1 Foot.



J.E.B. del. *J. Basire lith.*

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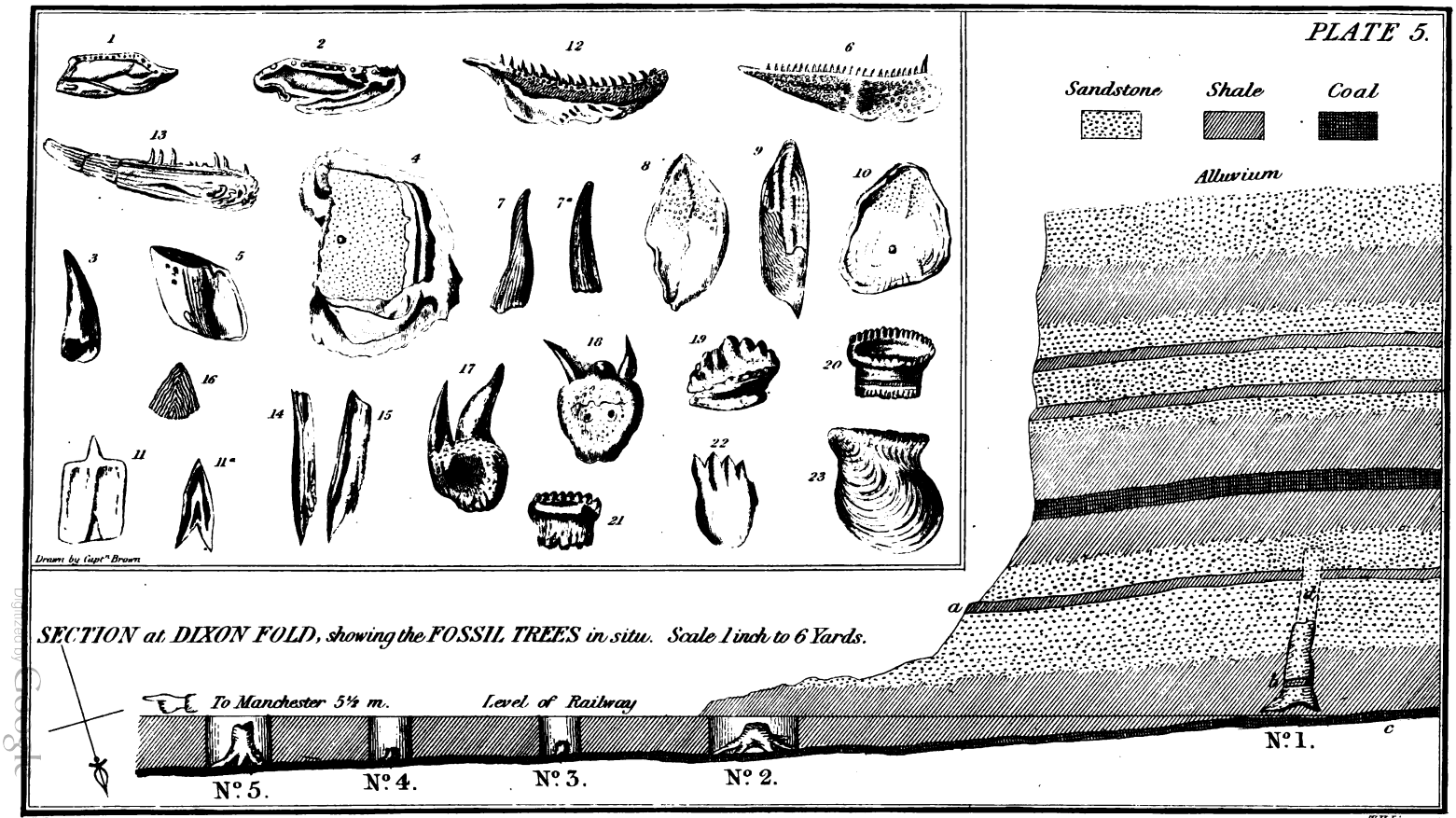

SECTION at DIXON FOLD, showing the FOSSIL TREES in situ. Scale 1 inch to 6 Yards.

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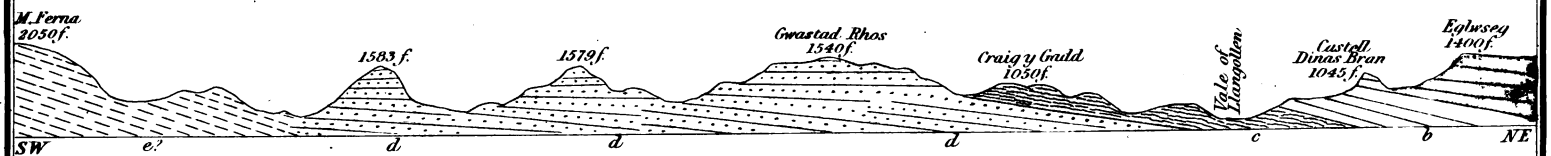
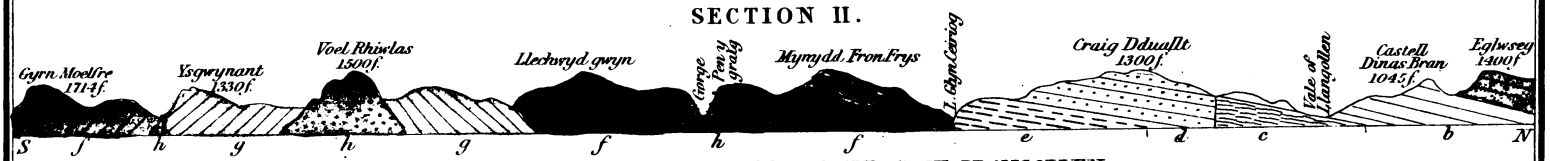
PLATE 6.

SECTION I.



UPPER SILURIAN ROCKS IN THE VALE OF LLANGOLLEN.

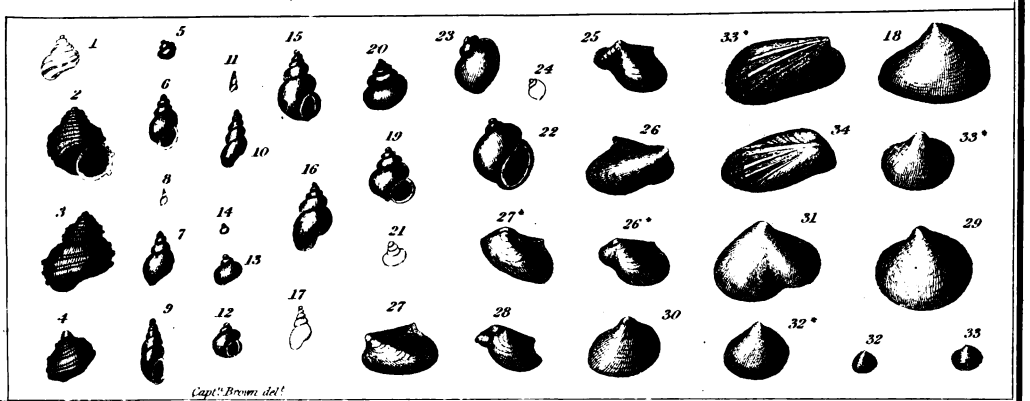
SECTION II.



TRAP PLATEAU E. OF THE BERWYN AND S. OF LLANGOLLEN.

Vertical & Horizontal Scale, 1 inch to 1 Mile.

Fig. 1.



J. E. H. del

W. H. Lizars sc.

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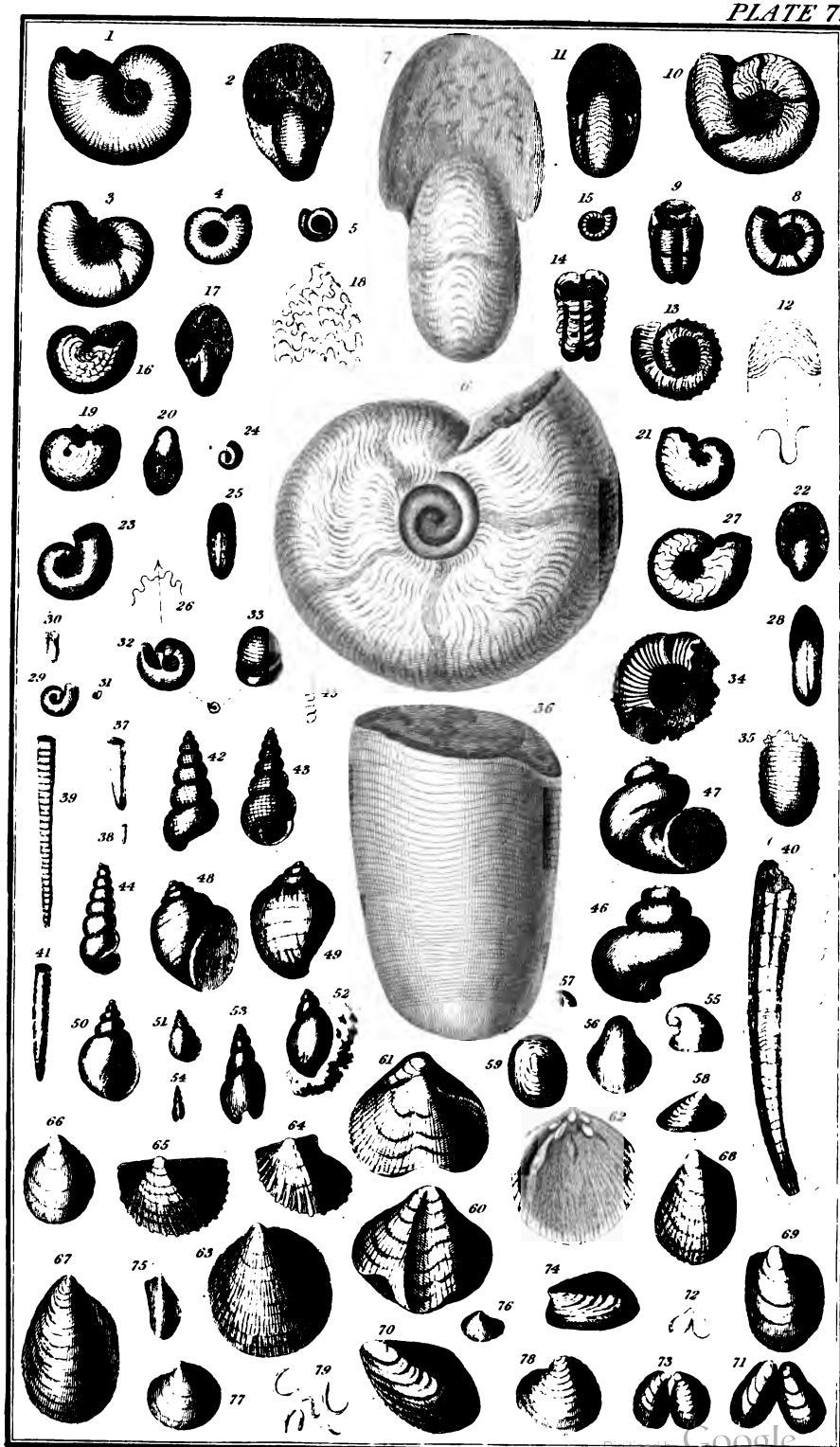

Drawn by Capt. Brown

Engd. by W.H. Lizars

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DIAGRAM No. 1

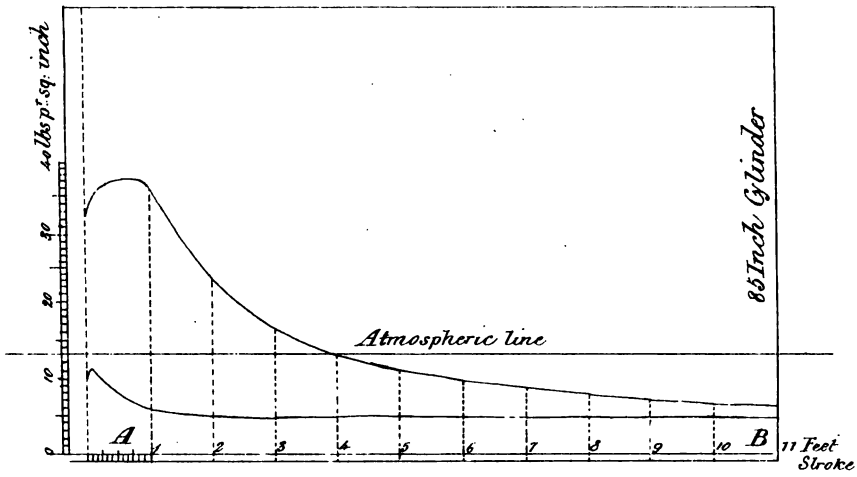


DIAGRAM No. 2

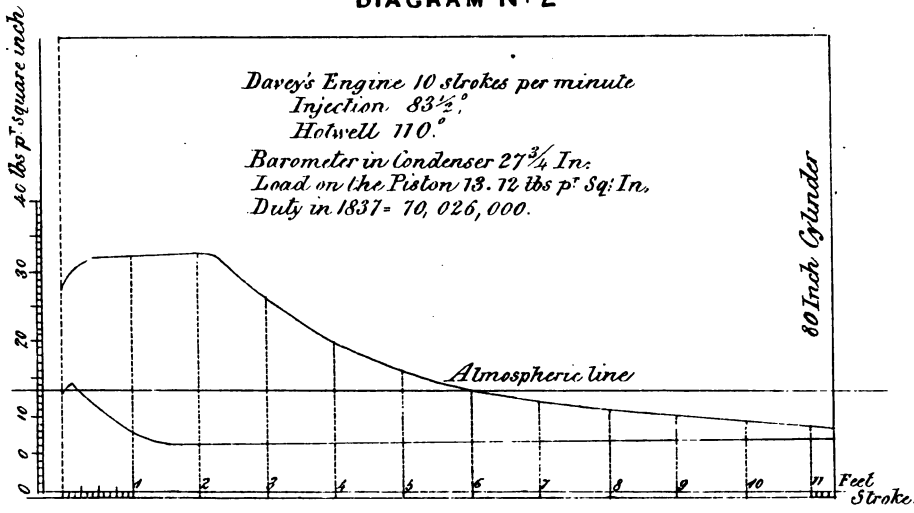
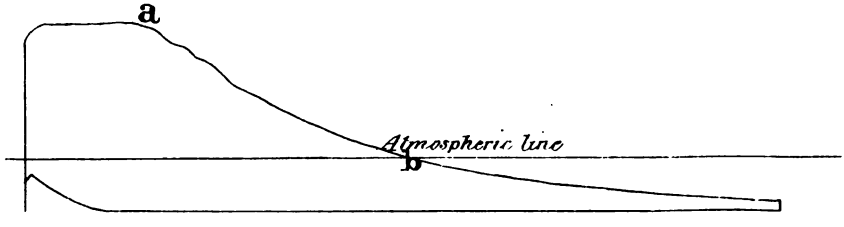


DIAGRAM No. 3

Hockings Engine 9 strokes per minute
Injection 52°
Hotwell 82
Load on Piston - 13. 58 lbs. pr. Sq. In.
Duty in 1837 - 67, 301, 000.



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T. Thwsick lith. Manchester.

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LIST

OF THE MEMBERS

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MANCHESTER

GEOLOGICAL SOCIETY.

30 SEPTEMBER, 1841.

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1840-41.

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Ashworth, Thomas, Barlow Fold, Poynton.
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Barker, William, The Hill, Oldham.
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Clay, Charles, Piccadilly, Manchester.
Clayton, D. T., Norbury.
Clayton, William, Hazel Grove.
Clegg, Abraham, Highfield, Oldham.
Clegg, James, Watershedding, Oldham.
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Coppock, Henry, Warren-street, Stockport.
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Darbishire, S. Dukinfield, Marsden-street, Manchester.
* Dawes, Matthew, F.G.S., Bolton.
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Emmott, George, Oldham.
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Faux, Edward, Irwell Castle, Pendleton.
Fleming, William, M.D., Broughton View, Salford.
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Fraser, J. W., Spear-street, Manchester.

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Glover, Thomas, 32, Mosley-street, Manchester.
Graham, John, Mayfield, Manchester.
Greaves, George, Egerton-terrace, Manchester.
Greaves, John, Vicar's Hill House, Lymington.
Green, James, Knowsley, Prescot.
Greenough, G. B., F.R.S. G.S. L.S. H.S. & M.R.A.S., Regent's Park, London.
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Greg, W. Rathbone, Chancery-lane, Manchester.
Grimshaw, Samuel, jun., M.A., Errwood, Buxton.

Hadfield, George, Fountain-street, Manchester.
Haliburton, Alexander F., Whitley, Wigan.
Hall, Elias, Castleton, Derbyshire.
Hall, Samuel, Lever-street, Manchester.
Hamilton, Thomas, Princess-street, Manchester.

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Harter, William, York-street, Manchester.
Hawkshaw, John, F.G.S., Bolton Railway Office, Salford.
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Heron, Joseph, 21, Princess-street, Manchester.
Hertz, James, 51, Mosley-street, Manchester.
Heywood, Sir Benjamin, Bart., Claremont, Manchester.
* Heywood, James, F.R.S. & G.S., Acresfield, Manchester.
Hick, Benjamin, Soho Works, Bolton.
Higson, Peter, Clifton, Bolton.
Hodgkinson, Eaton, F.R.S., 21, Granby-row, Manchester.
Holmes, Charles, Long Orrell Hall, Wigan.
Holroyde, Elkanah, Long Millgate, Manchester.
Horner, Leonard, F.R.S. L. & E. & G.S., 2, Bedford-place, London.
Hulton, William, F.G.S, Hulton Park, Bolton.
Hutton, W., F.G.S., Newcastle-upon-Tyne.

James, Paul Moon, Mosley-street, Manchester.
Jones, Joseph, jun., Walshaw House, Oldham.
Jones, William, Hope House, King-street, Oldham.

Kay, Alexander, Cross-street, Manchester.
Kirkman, Thomas, Springfield, Salford.
Knowles, Thomas, Pendlebury, Manchester.

Lacy, Edward, 22, Oxford-street, Manchester.
Langshaw, Captain, The Hollins, Bolton.
Langton, William, Saint Ann's-street, Manchester.
Lingard, J. R., Stockport.
Livesey, Thomas, Chamber Hall, Oldham.
Lees, Henry, Newton and Dukinfield Colliery.
Lees, James, Police-street, Manchester.
Longshaw, J., Pendleton, Manchester.
Looney, Francis, F.G.S., 8, Whittle-street, Manchester.
Lowe, John, 75, Great Jackson-street, Manchester.
Loyd, Edward, Bank, King-street, Manchester.

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Lyell, Charles, jun., M.A. F.R.S. G.S. & L.S., 16, Hart-street, Bloomsbury-square, London.
Lyon, Edmund, M.D., 11, Falkner-street, Manchester.

Malet, George, 5, Mawdsley-street, Bolton.
Mann, Robert, Great Bridgewater-street, Manchester.
Marsland, Martin, Stockport.
Marsland, Thomas, Stockport.
Meadows, James, Ashton Canal Office, Manchester.
Mellor, William, Ardwick.
Milne, Joshua, High Crompton, Oldham.
Moore, John, Clifton Colliery, Bolton.
Moore, John, F.L.S., Cornbrook House, Sale.
Moore, Thomas, Bolton.
Moore, William C., Mill-street, Ancoats, Manchester.
Morton, Charles, Darton, Barnsley.
Moult, William, Knowsley.
* Mulliner, Thomas, Clifton Colliery, Bolton.
Murchison, R. T., F.R.S. G.S. & L.S., 2, Upper Eccleston-street, Belgrave-square, London.

Nield, William, 5, Friday-street, Manchester.
Newbold, John S., M.D., 23, Falkner-street, Manchester.
Nicholson, William, 43, Princess-street, Manchester.
Norreys, R. J. J., Davyhulme Hall, Manchester.
Norris, Thomas, F.L.S., Redivales, Bury.
Norwich, Edward Stanley, D.D., Bishop of, F.G.S. & L.S., Palace, Norwich.

* Oaks, J., Ridding's Hall, Alfreton, Derbyshire.
Ogden, John, Oaks, Oldham.
Orford, Richard, High-lane, Stockport.
Ormerod, Edward, Portland-place, Manchester.
Ormerod, George, L.L.D. F.R.S. S.A. & G.S., Sedbury Park, Gloucestershire.
Ormerod, G. Wareing, M.A. F.G.S., Essex-street, Manchester.
Ormerod, Henry Mere, Essex-street, Manchester.

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Peace, William, Haigh, Wigan.
Peet, Thomas, Saint James's-square, Manchester.
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Phillips, Robert, Heybridge, Staffordshire.
Phillips, Shakspear, Chancery-lane, Manchester.
Pickford, Thomas, Dickinson-street, Manchester.
Poppleton, Charles, Higher Hillgate, Stockport.

Ramsden, Josh., Top Hill House, Clifton, Bolton.
Rayner, William, M.D., Stockport.
Read, William, Saint Mary's-gate, Manchester.
Roberts, Richard, Falkner-street, Manchester.
Robinson, R. W., M.D., Mosley-street, Manchester.
* Ross, William, Leaf-square, Salford.
Rothwell, Peter, Union Foundry, Bolton.

Satterfield, Joshua, Saint Ann's-square, Manchester.
Sedgwick, Rev. A., M.A. F.R.S. & G.S., Cambridge.
Sharp, Thomas, Falkner-street, Manchester.
Shuttleworth, John, Stamp Office, Manchester.
Simpson, Richard, Mellor Lodge, Marple, Cheshire.
Smith, J. A., Granby-row, Manchester.
Smith, G. S. Fereday, M.A. F.G.S., 2, Essex-street, Manchester.
Swire, Samuel, Portland House, Ashton.

Talbot, John Hawkshead, Wrightington, Wigan.
Taylor, John, Hargreaves, Oldham.
Taylor, John Edward, Manchester.
Taylor, Samuel, Eccleston Hall, Prescot.
Thicknesse, Ralph, jun., Wigan.
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Tootal, Edward, York-street, Manchester.
Tootal, Henry, York-street, Manchester.
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Wadsworth, George, 12, Princess-street, Manchester.
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* Walker, Samuel, Prospect Hill, Pendleton.
Walker, Rev. W. Fuller, Greenacres Moor.
Wallace, Rev. R., New College, Manchester.
Whewell, Rev. W., B.D. F.R.S. & G.S., Cambridge
Williamson, J. H., Stone Trough Colliery, Newcastle, Staffordshire.
Wilson, Thomas, Banks, Barnsley.
Wilson, W. J., Mosley-street, Manchester.
Winstanley, Thomas Woodcock, 2, Essex-street, Manchester.
Wood, W. Rayner, 14, Somerset-street, Manchester.
Woodcroft, Bennet, 7, Port-street, Manchester.

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